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Simulation of High Altitude Effects on Heavy-Duty Diesel Emissions

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Emission Control Technology Division
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**Simulation of High Altitude Effects on
Heavy-Duty Diesel Emissions**

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FOREWORD

The project on which this report is based was initiated by Work Assignment No. 1-8 of EPA Contract 68-03-4044, received by SwRI on October 31, 1988. The contract was for "Fuels and Emissions Characterization." Work Assignment No. 1-8 of that contract was specifically for "Simulation of High Altitude Effects on Heavy-Duty Diesel Emissions (continuation)." The work was identified within SwRI as Project No. 08-1567-008.

The Project Officer and the Technical Project Monitor for EPA during the Work Assignment were Mr. Craig A. Harvey and Mr. Thomas M. Baines, respectively. SwRI Project Director was Mr. Charles T. Hare, and SwRI Project Manager was Mr. Terry L. Ullman. The SwRI Task Leader and principal investigator for Work Assignment No. 1-8 was Mr. David M. Human. Technical supervisor was Mr. Ernest M. Krueger. Mr. Ullman was responsible for implementing the design of the High Altitude Simulation CVS concept initiated by EPA, and Mr. James R. Boylan was responsible for the fabrication of the unit and contributions to its design.

ABSTRACT

Exhaust emissions from heavy-duty diesel engines operating at high altitude are of concern. EPA and Colorado Department of Health sponsored this project to characterize regulated and selected unregulated emissions from a naturally-aspirated Caterpillar 3208 and a turbocharged Cummins NTC-350 diesel engine at both "low" and simulated "high" altitude conditions (≈ 6000 ft). Emissions testing was performed over cold- and hot-start transient cycles as well as selected steady-state modes. Additionally, the turbocharged engine was operated with mechanically variable and fixed retarded fuel injection timing to represent "normal" and "malfunction" conditions, respectively.

High altitude operation generally reduced NO_x emissions approximately 10 percent for both engines. Average composite transient emissions of HC, CO, particulate matter, and aldehydes measured at high altitude for the naturally-aspirated engine were 2 to 4 times the levels noted for low altitude conditions. The same emission constituents from the turbocharged engine at high altitude with "normal" timing were 1.2 to 2 times the low altitude levels, but were 2 to 4 times the low altitude levels with "malfunction" timing.

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I. INTRODUCTION

Heavy-duty diesel engines are believed to be significant contributors to ambient air pollution at high altitude locations such as the Denver, Colorado area. The Environmental Protection Agency (EPA) and the Colorado Department of Health (CDH) have collected a large amount of light-duty vehicle emissions data at high altitude using the test facilities of CDH. However, no high altitude facilities are available to fully characterize heavy-duty diesel emissions using the EPA transient emissions test procedure and the smoke test procedure. Some way to characterize emissions at high and low altitude using comparable methods was needed to help determine strategies to reduce high altitude heavy-duty diesel emissions.

One way to accomplish this emissions characterization would be to construct a full heavy-duty transient test facility in Denver, but the cost and lead-time for an operational facility is of concern. Another option, presented here, was to construct equipment to simulate high altitude conditions at an existing test facility. In addition to the cost and lead-time advantages of this approach, there is also the elimination of indeterminate high altitude lab to low altitude lab correlation differences that could overshadow any altitude-related emission changes that the test program would identify.

This report describes the high altitude simulation CVS and the procedures which were used to validate the proper operation of the system. The procedures utilized to measure regulated and unregulated emissions also are described in this report. Results obtained during high and low altitude transient and steady-state emission testing of a naturally aspirated and a turbocharged heavy-duty diesel engine are presented.

II. SUMMARY

Both regulated and unregulated emissions from two heavy-duty diesel engines were shown to be substantially affected by changes in altitude. A high altitude simulation CVS, developed in this program, allowed emissions from two engines to be measured at both "low" altitude and simulated "high" altitude at a single emissions testing location. For the purposes of this report, high altitude corresponds to approximately 1800 meters (6000 feet) above sea level or a nominal barometric pressure of 610 millimeters (24 inches) Hg. Low altitude corresponds to the local elevation at Southwest Research Institute of approximately 240 meters (800 feet) above sea level with an average observed barometric pressure of 740 millimeters (29 inches) Hg.

A naturally aspirated Caterpillar 3208 and a turbocharged Cummins NTC-350 were tested using the high altitude simulation CVS to measure both transient and steady-state emissions. For transient test work, a "full rack" torque-map from idle to above rated speed is required. During the map, observed full rack torque output for low engine operating speeds at high altitude conditions was significantly lower than the torque observed at low altitude for both naturally aspirated and turbocharged engines.

The turbocharged Cummins NTC-350 engine produced 15 to 30 percent less torque at high altitude than at low altitude conditions at speeds less than 1200 rpm. The bulk of this reduction in low speed torque output may be due to different response of an aneroid system within the governor at high altitude. However, a portion of the torque reduction in the low speed range of operation, where the turbocharger typically provides low levels of boost, is attributed to reduced utilization of the fuel at high altitude. After the turbocharger became effective, between intermediate and rated speeds, the engine delivered "full rack" torque at high altitude conditions equal to that observed at low altitude. The full rack torque for the naturally aspirated Caterpillar 3208 at high altitude was approximately 12 percent lower than at low altitude conditions over most of the engine speed range.

Regulated emissions of total hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and total particulate matter (PM) were determined for EPA transient tests^{(1)*} and two steady-state conditions at both high and low altitude. The steady-state modes for both the naturally aspirated and turbocharged engines were curb idle speed with zero load and intermediate speed with 50 percent load. Unregulated emissions of aldehydes, the volatile fraction of PM, and brake specific fuel consumption (BSFC) also were determined. Regulated smoke opacity factors were determined for the EPA smoke test.⁽²⁾ The EPA transient test command cycle used for both high and low altitude tests of a selected engine was the same and was generated using the low altitude engine performance map. This strategy assumes that the engines were to perform this same amount of work at high altitude as normally performed at low altitude. The high altitude performance map was taken for comparative purposes.

The Cummins NTC-350 utilized mechanical variable timing (MVT) of fuel injection to adjust timing to an advanced position at loads less than 25 percent and to a retarded position at loads greater than 25 percent. A "malfunction" mode of operation was simulated by disabling the MVT to a fixed retarded timing setting. Results from brief reference tests indicated that the emissions from the Cummins NTC-350 with fixed retarded timing were affected by high altitude substantially more than with the MVT operating normally.

*Numbers in parentheses designate references at the end of this report.

Average composite transient emission and smoke test results for the Caterpillar 3208 and for the Cummins NTC-350 are given Tables 1 and 2, respectively. Average composite transient emissions of HC, CO, PM, and total aldehydes measured at high altitude for the naturally aspirated Caterpillar 3208 and for the turbocharged Cummins NTC-350 in a "malfunction" configuration were 2 to 4 times the levels noted for low altitude conditions (with the MVT operating normally, hot-start high altitude CO and PM emissions were 2 and 1.5 times the low altitude levels, respectively, as shown later in Table 12). Composite transient NO_x levels for both engines decreased approximately 10 percent from low altitude to high altitude. Volatile percentages of PM increased 7 percent for the Caterpillar 3208, and increased 70 percent for the "malfunction" configuration of the Cummins NTC-350 at high altitude. Average smoke levels from EPA smoke tests increased 92 percent for the Caterpillar 3208 and 36 percent for the Cummins NTC-350 from low altitude to high altitude conditions. At high altitude, greater increases in HC, CO, and smoke emission levels were noted for the Caterpillar 3208 than for the Cummins NTC-350 in "malfunction" configuration. However, for PM and total aldehydes, greater increases were noted for the Cummins NTC-350 in "malfunction" configuration than for the Caterpillar 3208 at high altitude. Relative to low altitude, high altitude composite transient BSFC was 15 percent higher for the Caterpillar 3208, and it was 3 percent higher for the Cummins NTC-350 in the "malfunction" configuration.

Steady-state conditions of idle and intermediate speed produced altitude-dependent emission trends similar to those noted for transient testing; however, individual emission constituents were sometimes more or less sensitive to the high altitude conditions. Even though the Cummins engine was tested in a "malfunction" configuration, its emissions were generally less sensitive to the effects of high altitude than the Caterpillar 3208. Much of the reduced emission sensitivity of the Cummins NTC-350 was attributed to use of a turbocharger.

TABLE 1. AVERAGE COMPOSITE TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CATERPILLAR 3208

TEST DESCRIPTION	HC	CO	g/kw-hr (g/hp-hr)			ALDEHYDES	BSFC	VOLATILES % of PM	Smoke, % Opacity		
			NOx	PM					"A"	"B"	"C"
Low Altitude Average	1.21 (0.90)	7.35 (5.48)	12.9 (9.63)	0.83 (0.63)		0.33 (0.25)	0.305 (0.503)	27	19	23	25
High Altitude Average	5.04 (3.76)	28.0 (20.9)	11.5 (8.59)	1.8 (1.3)		0.84 (0.62)	0.350 (0.575)	29	36	37	56

TABLE 2. AVERAGE COMPOSITE TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CUMMINS NTC-350 (a)
WITH FIXED RETARDED TIMING (MALFUNCTION)

TEST DESCRIPTION	HC	CO	g/kw-hr (g/hp-hr)			ALDEHYDES	BSFC	VOLATILES % of PM	Smoke, % Opacity		
			NOx	PM					"A"	"B"	"C"
Low Altitude Average	3.52 (2.63)	5.88 (4.38)	5.11 (3.81)	1.2 (0.92)		0.45 (0.34)	0.281 (0.462)	17	32	7.6	40
High Altitude Average	10.5 (7.84)	11.6 (8.66)	4.61 (3.44)	3.1 (2.3)		1.2 (0.88)	0.290 (0.478)	29	39	10	59

(a) Hot-start transient and idle emission results for the Cummins NTC-350 with variable timing operating normally can be found in Table 12.

III. TEST PLAN AND DESCRIPTION OF CVS, ENGINES, AND PROCEDURES

The objective of this assignment was to design, develop, and validate a constant volume sampler (CVS) to simulate high altitude conditions during operation of a diesel engine on the Federal transient cycle. This section describes the test plan and high altitude simulation CVS. Included in this section are descriptions of the two test engines along with test procedures used to acquire high and low altitude results. In addition, a Quality Assurance segment that addresses the precision, accuracy, and completeness of the test program is contained in this section.

A. Test Plan

Task 1 of the test plan involved the design, development, and validation of a high altitude simulation CVS. The system was envisioned to be capable of providing reduced atmospheric pressure to both the intake and exhaust of a test engine, thus simulating high altitude. The reduced pressure was to be equivalent to atmospheric pressure normally occurring at approximately 1800 meters (6000 feet) of altitude above sea level.

Task 2 involved transient and steady-state emission testing at (simulated) high and low altitude conditions. A medium-duty naturally aspirated diesel engine and a heavy-duty turbocharged diesel engine were each to be tested for emissions, at both high and low altitude conditions, over EPA transient tests and steady-state conditions including idle and intermediate speed with 50 percent load. Federal smoke tests were also to be conducted on both engines at high and low altitude conditions.

Total hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO₂), and oxides of nitrogen (NO_x) emissions were to be measured segment by segment for transient testing. Total particulate matter (PM) was to be determined using sample filters acquired during both cold-start and hot-start cycles that make up the complete EPA transient test. Additional filters were to be taken for potential analysis of nitrate, sulfate, and carbon by EPA. Individual and total aldehyde emissions were to be determined for cold-start and hot-start cycles of the EPA transient test. In addition, all of these exhaust emissions were to be measured at high and low altitude conditions for two steady-state modes consisting of curb idle and intermediate speed with 50 percent load.

B. High Altitude Simulation CVS

A special CVS unit was constructed to simulate high altitude operation of internal combustion engines for the purpose of exhaust emissions measurement during transient testing. Figure 1 shows the high altitude simulation CVS and the control unit which collects data and gaseous samples. A side view of the CVS shows the heated sample probe and 90 millimeter particulate collection system in Figure 2. The CVS was constructed such that engine intake air is taken from the CVS, and engine exhaust is returned to the CVS, in an area which can be maintained at low pressure relative to local or ambient atmospheric pressure. During high altitude simulations, the main dilution tunnel pressure was maintained at approximately 81 KPa absolute (24 inches Hg) to simulate 1800 meters (6000 feet) above sea level. Maximum pressure variation observed in the tunnel was within 2 KPa (0.6 inches Hg) of nominal during transient testing. The CVS system is capable of maintaining tunnel pressures which simulate altitudes ranging from local to 3050 meters (10,000 feet) above sea level for selected engine test cycles or conditions.

This special CVS used a 610 millimeter (24 inch) diameter main dilution tunnel constructed of stainless steel. Total flow capacity of this positive-displacement CVS was set for a nominal flow of 57 SCMM (2000 SCFM). The flow rate can be adjusted to meet restricted dilution requirements of different engine sizes, and is controlled by positive-displacement pump (PDP) drive ratio and limited by electrical power requirements. PDP inlet air temperature stability over transient operation was provided by a large tube and fin heat exchanger. Dilute exhaust samples were taken 1.37 meters (54

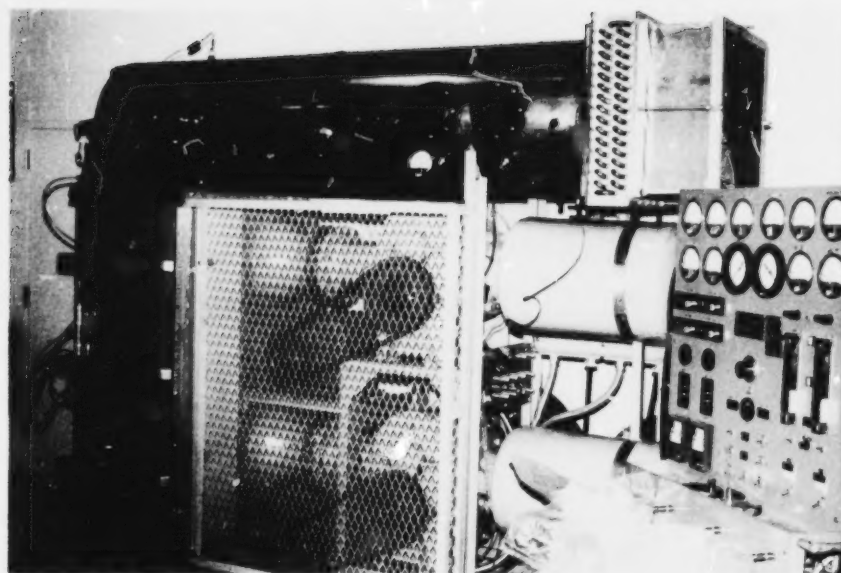


FIGURE 1. HIGH ALTITUDE SIMULATION CVS WITH CONTROL UNIT

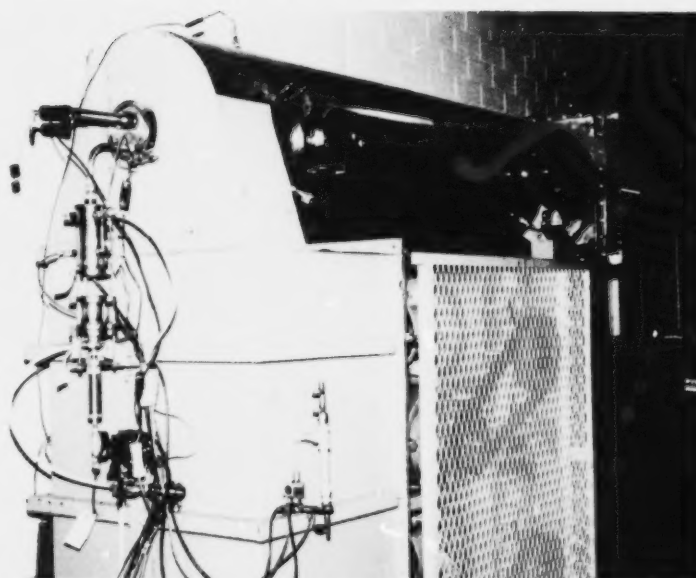


**FIGURE 2. SIDE VIEW OF HIGH ALTITUDE CVS SHOWING
HEATED SAMPLE PROBE FOR GASEOUS EMISSIONS AND 90 mm
DOUBLE DILUTION PARTICULATE COLLECTION SYSTEM**

inches) downstream of the exhaust entry into the CVS. Exhaust and dilution air were mixed in a very short distance within the dilution tunnel by using a series of orifice plates. Good mixing was confirmed by performing stratification checks using propane.

CVS dilution air, which also served as engine intake air during altitude simulation, was filtered using an MSA Dustfoe filter to reduce background particulate contamination. Temperature of the dilution air was controlled by a fin and tube heat exchanger located immediately downstream of the dilution air filter. No special treatment of intake air humidity was performed, so engine intake air water vapor ranged from 7 to 19 grams/kilogram of air (50 to 130 grains/pound of air). A controlled pressure drop was made to occur after the dilution air heat exchanger using a series of perforated plates. Adjustment of perforated plate alignment was used to achieve the desired atmospheric pressure drop. Engine inlet depression and exhaust backpressure were set using in-line dampers to provide the desired restrictions relative to CVS atmospheric pressure. Because engine intake air was removed from the CVS and exhaust gases were returned to the CVS, there was concern that unintentional mixing of exhaust gases with inlet air might occur. A special baffle was incorporated to isolate the exhaust and intake air streams. The lack of diesel soot on the entry of the engine intake air duct confirmed that there was no exhaust gas recirculation within CVS during testing.

Proportional dilute exhaust samples were withdrawn from the main dilution tunnel for gaseous and particulate emission determinations. The dilute gaseous sample stream was taken from the tunnel using a heated 190°C (375°F) sample train including a heated filter to remove particulate contamination. After filtration, the gaseous sample was pumped to a heated vent tube, bringing the sample to atmospheric pressure so that samples for HC, CO, CO₂, NO_x, and other gaseous constituents could be measured in a manner consistent with EPA protocols for heavy-duty diesel emission measurement. Particulate measurements were made using a double dilution technique. A proportional dilute exhaust sample was taken from the main tunnel and diluted further in a small secondary tunnel before it was passed through two 90 millimeter (3.5 inch) diameter filters in series. The particulate system accumulated the particulate sample on the filters at whatever pressure was set by the CVS operation; therefore, some particulate aerosols that may be pressure-temperature sensitive were allowed to react as they would for either high or low altitude.

C. Description of Engines

Two EPA-supplied diesel engines were used in this test work. Reference information for the Caterpillar 3208 and the Cummins NTC-350 is given in Tables 3 and 4, respectively. The Caterpillar 3208 is a 1980 model year, medium-duty, naturally aspirated, 10.4 liter displacement, V-8 diesel engine rated at 160 kilowatts (210 horsepower) at 2800 rpm. Figure 3 shows the Caterpillar 3208 mounted in the transient capable test cell and fitted with intake and exhaust pipes routed to the high altitude CVS. Emission testing was performed with the engine in a "stock" configuration. As required for naturally aspirated engines, blow-by gases are returned to the intake manifold. This engine uses a regulator valve to control crankcase pressure, and it is located between one valve cover and the intake manifold. The rubber blow-by tubing which connects the regulator valve to the intake manifold was reinforced to withstand increased manifold vacuum at simulated high altitude conditions. The regulator valve released crankcase pressure at 1.25 KPa (5 inches water) above atmospheric pressure. During high altitude simulation, the regulator valve was not referenced to simulated reduced atmospheric pressure; therefore, the crankcase did not experience the simulated altitude. A potential increase in oil sump ventilation due to increased pressure differential across the crankshaft seals was prevented by avoiding crankcase pressures below atmospheric.

The Cummins NTC-350 is a 1984 model year, heavy-duty, turbocharged, 14.0 liter displacement, in-line 6 cylinder diesel engine rated at 260 kilowatts (350 horsepower) at 2100 rpm. Figure 4 shows the Cummins NTC-350 mounted in the transient capable test cell and fitted with intake and exhaust pipes routed to the high altitude CVS. Mechanical variable timing (MVT) of fuel injection is utilized on this engine. The MVT system retards fuel injection at loads greater than approximately

TABLE 3. OBSERVED TEST PARAMETERS FOR CATERPILLAR 3208

<u>Test Parameter</u>	<u>Observed</u>
Intake restriction (Transient Cycle)	15 in. H ₂ O
Exhaust restriction (Transient Cycle)	2.2 in. Hg
Intake restriction (Federal Smoke)	15 in. H ₂ O
Exhaust restriction (Federal Smoke)	2.2 in. Hg
Rated engine speed	2800 rpm
Rated engine horsepower	200 hp
Fuel rate at rated speed and load	83.8 lb/hr
Fuel temperature at rated speed and load	98 min. 102 max. °F
Peak torque speed	1680 rpm
Peak torque	444 ft-lb
Fuel rate at peak torque speed	53.1 lb/hr
High idle (governed)	3028 rpm
Low idle (curb idle)	628 rpm
Water outlet temperature	190°F
Cranking speed	300 rpm
Engine oil, SAE rating	30 wt.
Engine coolant type	H ₂ O + Rust Inhibitor

TABLE 4. OBSERVED TEST PARAMETERS FOR CUMMINS NTC-350

<u>Test Parameter</u>	<u>Observed</u>
Intake restriction (Transient Cycle)	20 in. H ₂ O
Exhaust restriction (Transient Cycle)	2 in. Hg
Intake restriction (Federal Smoke)	20 in. H ₂ O
Exhaust restriction (Federal Smoke)	2 in. Hg
Rated engine speed	2100 rpm
Rated engine horsepower	343 hp
Fuel rate at rated speed and load	136.5 lb/hr
Fuel temperature at rated speed and load	98 min. 102 max. °F
Peak torque speed	1300 rpm
Peak torque	1084 ft-lb
Fuel rate at peak torque speed	97 lb/hr
High idle (governed)	2352 rpm
Low idle (curb idle)	690 rpm
Water outlet temperature	185°F
Cranking speed	300 rpm
Pressure drop across intercooler	6 in. H ₂ O
Air temperature after intercooler	190°F
Engine oil, SAE rating	30 wt.
Engine coolant type	H ₂ O + Rust Inhibitor

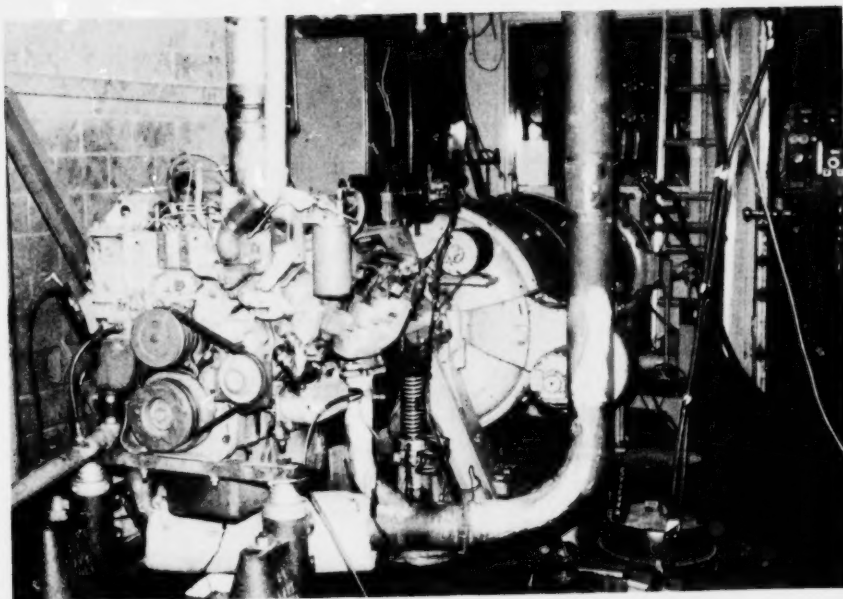


**FIGURE 3. CATERPILLAR 3208 IN TRANSIENT TEST CELL
WITH INTAKE AND EXHAUST SYSTEMS CONNECTED
TO HIGH ALTITUDE SIMULATION CVS**

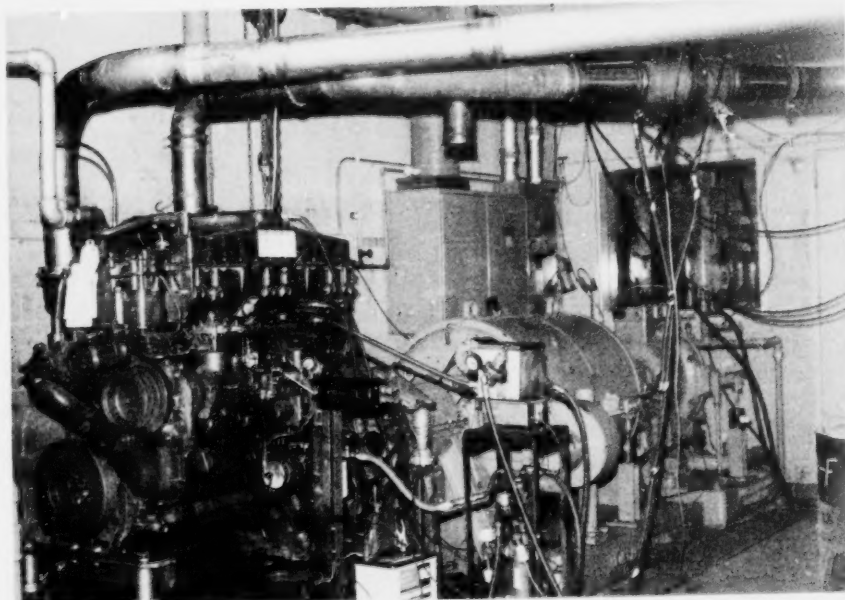


**FIGURE 4. CUMMINS NTC-350 IN TRANSIENT TEST CELL
WITH INTAKE AND EXHAUST SYSTEMS CONNECTED TO
HIGH ALTITUDE SIMULATION CVS**

25 percent. For test purposes, the MVT was fixed in the retarded timing position to examine a worst case malfunction of the device. Blow-by from the turbocharged Cummins NTC-350 is normally vented to atmosphere and is not included as part of the engine exhaust emissions. The engine uses an air-fuel control system to restrict fuel flow until sufficient boost pressure is achieved. The system is referenced to atmospheric pressure through the normally vented crankcase. For tests at high altitude, the blow-by vent tube was connected to a point downstream from the sample zone of the CVS to bring the crankcase to approximately the same pressure presented to both intake and exhaust systems. Pressure within the crankcase was maintained at simulated altitude since the blow-by vent was the only unsealed opening in the crankcase. Blow-by flow was monitored using an orifice flow meter and was found to be nominally 0.15 SCMM (5 SCFM).

D. Test Procedures

Transient testing was performed using procedures described in the U.S. Code of Federal Regulations (CFR) 40, Part 86, Subpart N. Emissions reference D-2 diesel fuel coded EM-834-F was used during the high altitude simulation project. Results of the fuel analyses performed by the refiner and SwRI are given in Table 5. The engine was operated through a variable engine speed and load schedule that makes up the transient cycle, requiring rapid dynamometer control capable of loading the engine one moment and motoring it the next. The transient cycle is described by 1199 one second torque and speed conditions based on engine performance. The test cycle is composed of four segments as described below.

<u>Segment</u>	<u>Time, sec</u>
New York Non-Freeway (NYNF)	297
Los Angeles Non-Freeway (LANF)	300
Los Angeles Freeway (LAF)	305
New York Non-Freeway (NYNF)	297

The resultant speed and torque commands for a 190 kilowatt (250-horsepower) diesel engine are shown graphically in Figure 5 as an example. A "Transient Test" consists of a cold-start and a hot-start transient cycle. The same engine control cycle is used in both cases. Prior to the cold-start, the engine was operated over a "prep" cycle, then allowed to stand overnight in an ambient soak temperature of 20 to 30°C (68 to 86°F). The cold-start transient cycle emission test began when the engine was cranked for cold start-up. On completion of this cycle, emission sampling was discontinued and the engine was shut down and allowed to stand for 20 minutes. After this hot soak period, the hot-start transient cycle emission test began with engine cranking. After completion of both cold-start and hot-start cycles, transient composite emissions in grams per kilowatt-hour (grams per horsepower-hour) were computed according the following formula: $[(1/7 \times \text{cold-start mass}) + (6/7 \times \text{hot-start mass})] / [(1/7 \times \text{cold-start work}) + (6/7 \times \text{hot-start work})] = \text{Composite transient emission value}$.

The engine to be tested was mounted on the test stand and its flywheel connected to the dynamometer with a drive shaft torquemeter. Exhaust and intake systems were connected between the engine and high altitude simulation CVS unit. During low altitude testing, the engine intake air system was disconnected from the CVS and the tunnel dilution air inlet restrictor was adjusted to create minimal restriction. For high altitude simulation, the engine intake was connected to the CVS and the inlet restrictor of dilution air was adjusted to produce 17 KPa (70 inches of H₂O) differential vacuum in the tunnel with respect to local atmospheric pressure. At 17 KPa (70 inches H₂O), the CVS simulated an altitude of 1800 meters (6000 feet) elevation or a 610 millimeter (24 inch) Hg barometer.

The engines were torque-mapped at low altitude conditions and a transient command cycle was generated. This transient command cycle was used for both low and high altitude tests. This strategy assumes the engines were to perform the same amount of work at high altitude as normally performed

DEPARTMENT OF EMISSIONS RESEARCH



TABLE 5.
DIESEL EMISSIONS FUEL SPECIFICATIONS
QUALITY ASSURANCE

FUEL TYPE 1-D _____ 2-D X SUPPLIER Phillips 66
LOT NO. K-146 SwRI CODE EM-834-F

Item	CFR Specification ^a			Supplier Analyses	SwRI Analyses
	ASTM	Type 1-D	Type 2-D		
Cetane	D613	48-54	42-50	45.5	44.0
Distillation range:					
IBP, °F	D86	330-390	340-400	367	366
10% Point, °F	D86	370-430	400-460	426	410
50% Point, °F	D86	410-480	470-540	505	499
90% Point, °F	D86	460-520	550-610	582	583
EP, °F	D86	500-560	580-660	651	644
Gravity, API	D287	40-44	33-37	34.9	34.9
Total Sulfur, %	D129 or D2622	0.05-0.20	0.2-0.5	0.28	0.262
Hydrocarbon Composition:					
Aromatics, %	D1319	8 ^b	27 ^b	33.1	35.8
Paraffins, Naphthenes, Olefins	D1319	c	c	66.9	64.2
Flashpoint, °F (min.)	D93	120	130	159	160
Viscosity, Centistokes	D445	1.6-2.0	2.0-3.2	2.4	2.43

^aDiesel fuel specifications as in CFR 86.113-82(b)(2) for light-duty diesel vehicles and CFR 86.1313-84(b)(2) for heavy-duty diesel engines.

^bMinimum

^cRemainder

Supplier Analyses

Date 11/28/88

SwRI Analyses

by Mary Fernandez

Date 12/5/88

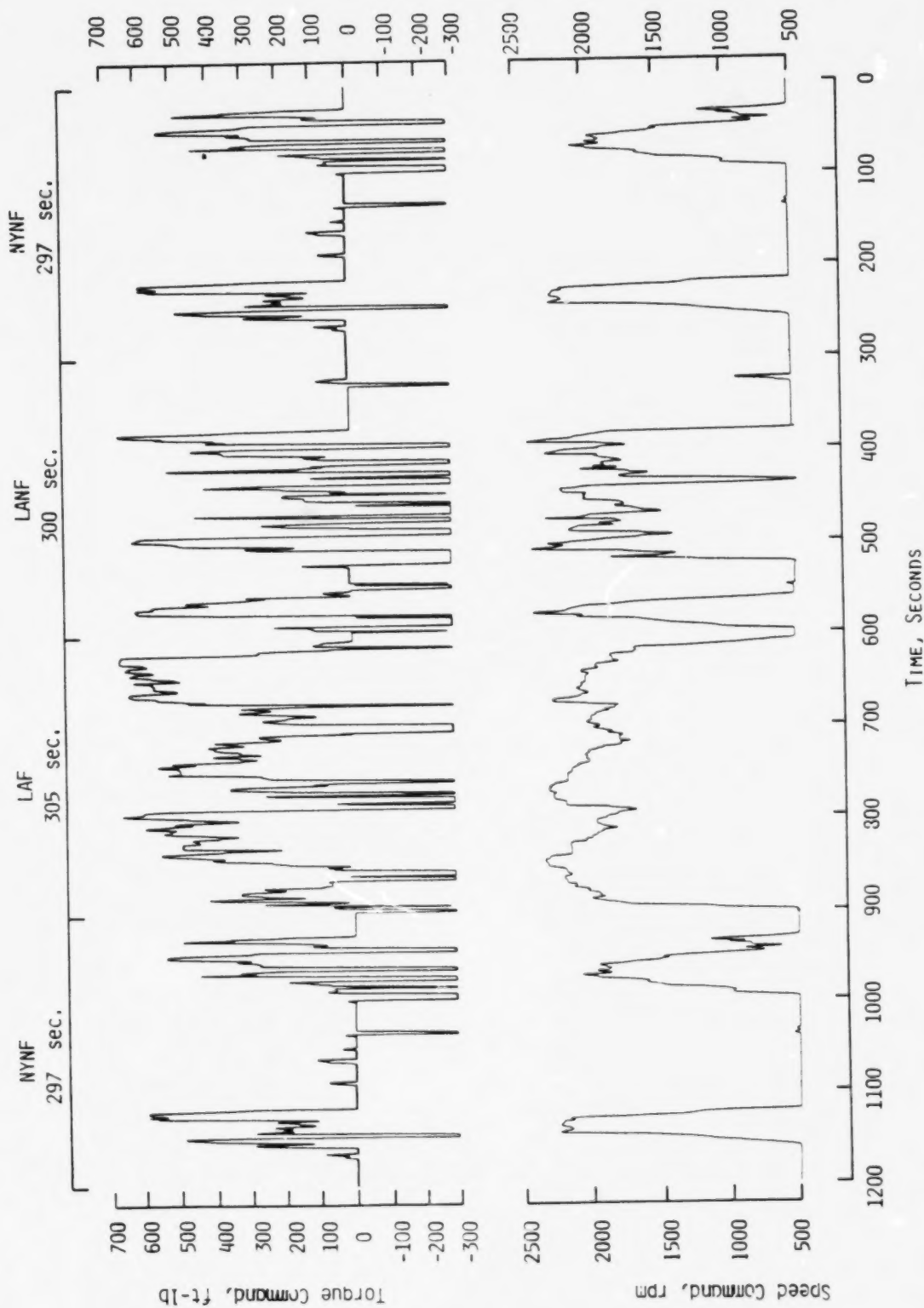


FIGURE 5. EXAMPLE OF TORQUE AND SPEED COMMANDS FOR A 250 HP DIESEL EPA TRANSIENT CYCLE

at low altitude. An engine torque-map was determined at high altitude for the purpose of performance comparison only.

During both transient and steady-state emissions testing, the use of a constant volume sampler (CVS) permitted dilution of the raw exhaust with air while metering the flow of the diluted mixture. Proportional samples of diluted exhaust were collected in sample bags to provide integrated values for carbon monoxide (CO) and carbon dioxide (CO₂). Brake specific fuel consumption (BSFC) was determined by the "carbon balance" method. Total hydrocarbons (HC) and oxides of nitrogen (NO_x) were measured continuously from a proportional sample of the dilute mixture and were integrated electronically over the test period. A double dilution tunnel permitted an initially diluted proportional sample to be diluted further, then filtered by two 90 millimeter diameter fluorocarbon coated glass fiber filters for the measurement of diesel particulate matter (PM).

Attempts to collect additional particulate samples from the main dilution tunnel were made for detailed analysis of the particulate by EPA. Two 47 millimeter diameter Fluoropore filters were intended for use in sulfate and nitrate analysis and one 47 millimeter diameter quartz fiber filter was intended for use in carbon analysis. During transient testing, it was observed that the pressure drop for all three 47 millimeter filters would increase, indicating that the filters were heavily loaded with PM during the first half of the transient cycle, causing loss of proportional flow control through the filters. During the midpoint of the LAF portion of the transient cycle, dilute exhaust temperatures in the main dilution tunnel increased substantially, and the pressure drop across the filter decreased indicating that the PM collected may have revolatilized. The change was substantial enough to allow proportional flow to be regained and maintained for the remainder of the cycle. Therefore, although analysis of these additional particulate filters may be useful for gross comparisons, they are likely not representative of the "total particulate" collected using the double dilution technique.

Aldehydes and ketones were determined using the 2,4-dinitrophenylhydrazine (DNPH) method.⁽³⁾ Proportional dilute exhaust samples were taken from the CVS dilution tunnel using a heated Teflon sample line and filter maintained at 190°C (375°F). A portion of the total sample transferred to atmospheric pressure was bubbled through glass impinger traps containing a solution of DNPH and hydrochloric acid kept near 0°C (32°F). The aldehydes formed their respective phenylhydrazone derivatives (precipitates). These derivatives were removed by filtration, and subsequently extracted with pentane and evaporated in a vacuum oven. The remaining dried extract, which contains the phenylhydrazone derivatives, was dissolved in a specific volume of methanol with anthracene internal standard. A portion of this dissolved extract was injected into a liquid chromatograph and analyzed using an ultraviolet detector to separate formaldehyde, acetaldehyde, acrolein, acetone, propionaldehyde, crotonaldehyde, isobutyraldehyde, methylethylketone, benzaldehyde, and hexanaldehyde. The emission rates of these individual species were summed to yield total aldehyde emissions.

Vacuum volatilization was used to determine the mass percentage of volatiles in the total PM collected on the 90 millimeter filters. The filters were weighed prior to volatilization in a vacuum oven, then re-weighed after 2 hours in the oven at 225°C (437°F). The difference in weight (corrected for background volatiles associated with the filter) was then divided by the total particulate loading to result in volatile percentage of total PM.

Smoke measurements were performed using an in-line light extinction smokemeter while the engine was operated over the Federal smoke cycle. Light path ventilation was maintained using compressed air which was regulated with a critical flow orifice. The smoke cycle includes two full-rack accelerations in engine speed, a closed-rack deceleration, and a full-rack lug down deceleration in engine speed. The smoke results are essentially averaged from three runs of the smoke cycle, and calculated results are expressed in the form of "A", "B", and "C" factors corresponding to acceleration, lug, and peak smoke values.

E. Quality Assurance

Validation of the high altitude simulation CVS was accomplished using techniques described in the CFR for calibration and validation of typical heavy-duty CVS systems. Adequate mixing of engine exhaust and dilution air was verified by injecting propane into the operating CVS while continuously measuring HC concentrations at various locations within the "sample zone" plane. Measured HC concentrations were within 2 percent of the nominal level when monitored in one inch intervals in both horizontal and vertical traverses across the diameter of the CVS. Propane recovery checks were periodically conducted on the CVS at both atmospheric and simulated high altitude conditions to assure system integrity and accuracy. Calibrations and span checks of gaseous emission analyzers were periodically performed using gases that are traceable to the National Bureau of Standards (NBS). The torque meter was calibrated using NBS traceable weights. Statistical precision of the test procedure cannot be calculated because less than three data points were obtained for any one operating condition.

Part of the validation of the high altitude simulation CVS included preliminary hot-start transient test runs on the Caterpillar 3208 engine. Regulated emissions were measured in back-to-back tests utilizing a conventional CVS and the high altitude simulation CVS operated at low altitude conditions. These emission values from runs made with both CVS systems compared reasonably well with each other and to EPA-supplied values. These early results were useful in building confidence in the accuracy of the high altitude CVS mixing and sampling system strategies.

Completeness of the emission measurements (number of useable data points relative to number of requested data points) made during this program is given in Table 6. The reported data represent an overall completeness of 96 percent. With the exception of total particulate and aldehydes, all other emissions were 100 percent complete.

TABLE 6. COMPLETENESS OF EMISSION MEASUREMENTS

Completeness, useable data provided/data requested														
Emission Measurement	Caterpillar 3208						Cummins NTC-350							
	Transient			Steady-state			Transient				Steady-state			
	cold-start	hot-start	idle	50% load	cold-start	hot-start	cold-start	hot-start	idle	50% load	cold-start	hot-start	idle	50% load
	LA	HA	LA	HA	LA	HA	LA	HA	LA	HA	LA	HA	LA	HA
Total HC	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
CO	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
CO ₂	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
NO _x	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
Particulate Matter (PM)	1/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
Volatile Percent of PM	1/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
Aldehydes	2/2	1/2	2/2	1/2	2/2	2/2	2/2	2/2	2/2	1/2	2/2	2/2	2/2	2/2
Sulfate filter	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
Nitrate filter	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
Carbon filter	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2

• LA = Low altitude HA = High altitude

IV. RESULTS

This section describes the results obtained from emission measurements conducted on a Caterpillar 3208 and a Cummins NTC-350 at simulated high and low altitude. Regulated transient emissions along with aldehydes and volatile percentage of the total particulate are discussed following a brief comparison of engine performance at high and low altitude conditions. Federal smoke test results are presented, followed by steady-state emissions data.

A. Emission Results from the Caterpillar 3208

Torque maps of the Caterpillar 3208 at both high and low altitude show that torque output was approximately 12 percent lower at high altitude conditions than at low altitude for the complete range of engine speeds. Figure 6 presents both high and low altitude torque maps for the Caterpillar 3208. The low altitude torque map was used to derive the transient test cycle used for both high and low altitude transient emission tests.

Regulated emissions of HC, CO, NO_x, and PM, as well as unregulated emissions of total aldehydes and percent volatiles are summarized for cold-start and hot-start transient tests in Tables 7 and 8, respectively. The NO_x value for the cold-start at high altitude, Run 2, was estimated from "sample bag" NO_x concentration because the continuous NO_x analyzer output was found to be erroneous after testing on the engine was completed. To estimate the continuous NO_x concentration, the bag reading was multiplied by 1.07 to adjust for the difference between continuous and bag NO_x values. The adjustment was calculated from noting the differences between continuous and bag NO_x values for other runs on this engine. For cold-start transient operation, high altitude caused substantial increases in all emissions except NO_x and percent volatiles, and BSFC increased by about 25 percent. For hot-start transient operation, the same trends were noted, but aldehyde and HC emission levels were not as high at high altitude as the levels noted for cold-start operation.

Composite transient emission results from high and low altitude tests are summarized in Table 9. Average composite transient HC and CO emissions at high altitude were almost four times the levels measured at low altitude. Average high altitude emissions of total particulate matter (PM) were double those for low altitude. Total aldehydes with high altitude operation were 2.5 times the low altitude composite transient emissions. Composite transient emission of NO_x at low altitude decreased 11 percent with high altitude operation. Low altitude composite transient BSFC increased 14 percent at high altitude. The percent of volatile PM for the Caterpillar 3208 was approximately the same under high and low altitude conditions.

As expected, smoke emissions increased dramatically at high altitude for the naturally aspirated Caterpillar 3208. This particular engine exceeded the EPA standard of 15 percent opacity for the "B" factor, even at low altitude conditions. The "B" factor, along with the other factors, increased to extremely high levels of smoke opacity at high altitude. Federal Smoke Test results are given in Table 10. Average smoke values for acceleration, lug, and peak increased between 61 and 124 percent during high altitude operation with respect to low altitude operation.

Two steady-state modes were selected for emissions evaluation at both high and low altitude. Idle emissions were taken during a 15 minute test with the dynamometer adjusted to approximately zero torque at curb idle. Intermediate speed mode emissions were measured during 15 minutes at 1680 rpm engine speed and 290 newton meters (215 foot-pounds) of torque. Steady-state emission results for the Caterpillar 3208 are presented in Table 11.

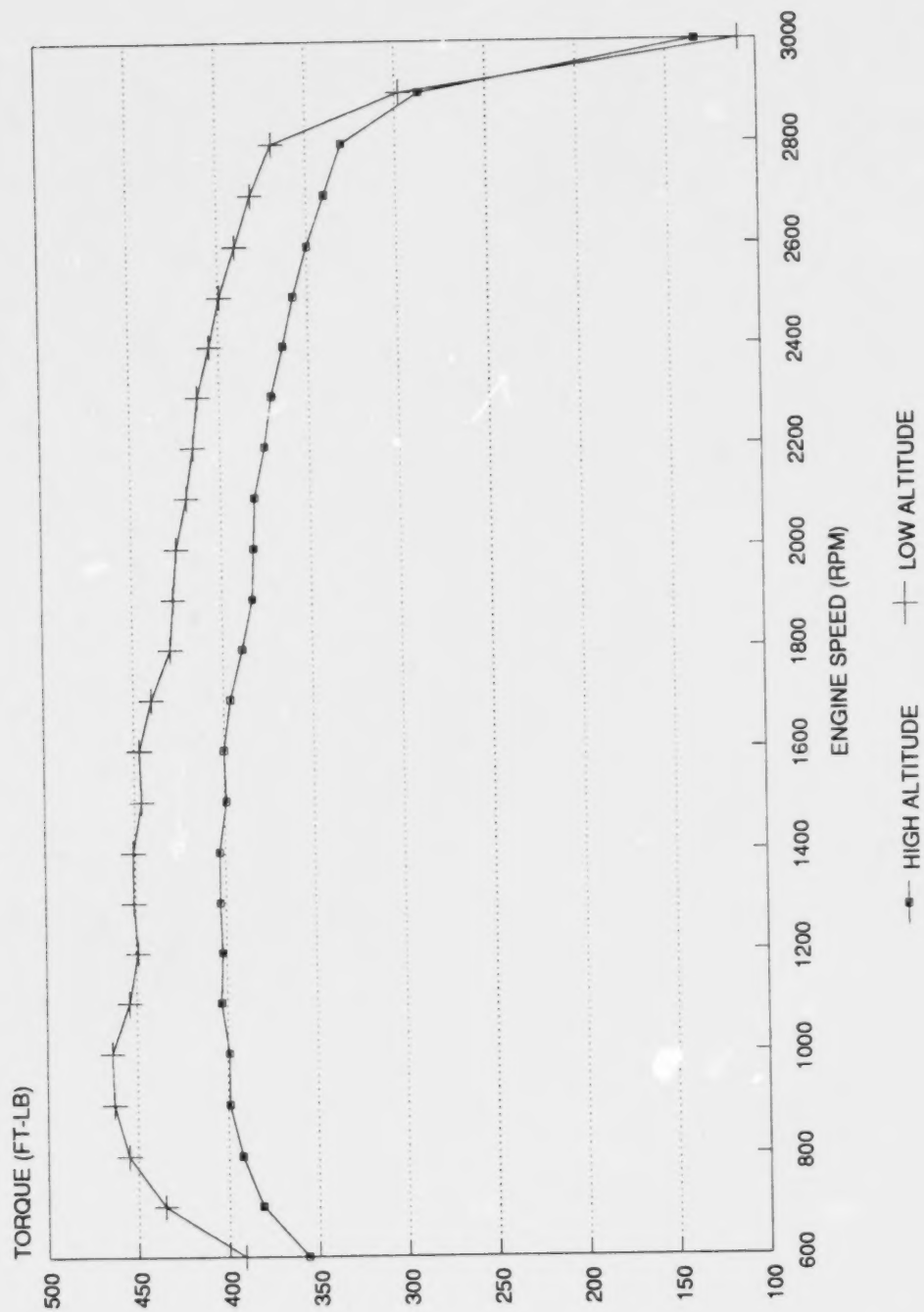


FIGURE 6. TORQUE MAP - CATERPILLAR 3208

TABLE 7. COLD-START TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CATERPILLAR 3208

TEST DESCRIPTION	HC	CO	NO _x	PM	ALDEHYDES	VOLATILES	BSFC
			g/kw-hr (g/hp-hr)			% of PM	kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	1.71 (1.28)	9.19 (6.85)	13.1 (9.76)	a	0.46 (0.34)	a	0.310 (0.509)
Low Altitude - Run 2	1.58 (1.18)	9.54 (7.12)	13.2 (9.86)	0.89 (0.67)	0.48 (0.36)	26	0.280 (0.460)
Low Altitude Average	1.65 (1.23)	9.37 (6.99)	13.2 (9.81)	0.89 (0.67)	0.47 (0.35)	26	0.295 (0.485)
High Altitude - Run 1	5.37 (4.01)	29.0 (21.6)	11.8 (8.80)	2.1 (1.5)	1.9 (1.4)	28	0.376 (0.618)
High Altitude - Run 2	6.44 (4.80)	23.7 (17.7)	10.8 (8.08)	1.6 (1.2)	c	29	0.363 (0.597)
High Altitude Average	5.91 (4.41)	26.4 (19.7)	11.3 (8.44)	1.8 (1.4)	1.9 (1.4)	29	0.370 (0.608)

a Particulate sampling system failure

b (Bag NO_x)(1.07) used due to continuous analyzer malfunction

c Aldehyde sampling failure

TABLE 8. HOT-START TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CATERPILLAR 3208

TEST DESCRIPTION	HC	CO	NOx	PM	ALDEHYDES	VOLATILES	BSFC
			g/kw-hr (g/hp-hr)			% of PM	kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	1.18 (0.88)	6.98 (5.20)	12.8 (9.56)	0.78 (0.58)	0.30 (0.22)	36	0.307 (0.505)
Low Altitude - Run 2	1.08 (0.80)	7.05 (5.25)	12.9 (9.63)	0.82 (0.62)	0.31 (0.23)	27	0.307 (0.505)
Low Altitude Average	1.13 (0.84)	7.02 (5.23)	12.9 (9.60)	0.80 (0.60)	0.31 (0.23)	32	0.307 (0.505)
High Altitude - Run 1	4.35 (3.24)	35.2 (26.2)	11.2 (8.38)	1.8 (1.3)	0.66 (0.49)	31	0.373 (0.613)
High Altitude - Run 2	5.44 (4.06)	21.4 (16.0)	11.9 (8.84)	1.8 (1.3)	a	27	0.320 (0.525)
High Altitude Average	4.90 (3.65)	28.3 (21.1)	11.6 (8.61)	1.8 (1.3)	0.66 (0.49)	29	0.347 (0.569)

a Aldehyde sampling failure

TABLE 9. COMPOSITE TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CATERPILLAR 3208

TEST DESCRIPTION	HC	CO	NO _x	PM	ALDEHYDES	VOLATILES	BSFC
			g/kw-hr (g/hp-hr)			% of PM	kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	1.26 (0.94)	7.30 (5.44)	12.9 (9.59)	a	0.32 (0.24)	a	0.307 (0.506)
Low Altitude - Run 2	1.15 (0.85)	7.41 (5.52)	13.0 (9.66)	0.83 (0.63)	0.33 (0.25)	27	0.303 (0.499)
Low Altitude Average	1.21 (0.90)	7.36 (5.48)	12.9 (9.63)	0.83 (0.63)	0.33 (0.25)	27	0.305 (0.503)
High Altitude - Run 1	4.50 (3.35)	34.3 (25.6)	11.3 (8.44)	1.8 (1.3)	0.84 (0.62)	31	0.373 (0.614)
High Altitude - Run 2	5.58 (4.17)	21.8 (16.2)	11.7 (8.73)	1.7 (1.3)	b	27	0.326 (0.535)
High Altitude Average	5.04 (3.76)	28.0 (20.9)	11.5 (8.59)	1.8 (1.3)	0.84 (0.62)	29	0.350 (0.575)

a Particulate sampling failure during cold-start

b Aldehyde sampling failure

TABLE 10. SMOKE TEST RESULTS
FROM HIGH ALTITUDE SIMULATION ON CATERPILLAR 3208

	Smoke Factor, % Opacity		
	"A"	"B"	"C"
EPA Standards	20	15	50
Low Altitude - Run 1	19	22	24
Low Altitude - Run 2	19	24	26
Low Altitude Average	19	23	25
High Altitude - Run 1	39	39	59
High Altitude - Run 2	33	34	53
High Altitude Average	36	37	56

TABLE 11. STEADY-STATE EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CATERPILLAR 3208

IDLE MODE

TEST DESCRIPTION	HC	CO	NOx	PM	ALDEHYDES	VOLATILES	FUEL
			g/hr (g/hr)			% of PM	kg/hr (lb/hr)
Low Altitude - Run 1	20.9	69.9	80.8	5.4	4.6	43	2.82
Low Altitude - Run 2	23.1	77.1	81.6	4.9	5.6	33	3.01
Low Altitude Average	22.0	73.5	81.2	5.2	5.1	38	2.92
High Altitude - Run 1	37.0	116	65.2	7.6	5.7	33	2.74
High Altitude - Run 2	43.0	106	76.2	9.4	a	40	2.97
High Altitude Average	40.0	111	70.7	8.5	5.7	37	2.86

INTERMEDIATE MODE

TEST DESCRIPTION	HC	CO	NOx	PM	ALDEHYDES	VOLATILES	BSFC
			g/kw-hr (g/hp-hr)			% of PM	kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	0.69 (0.51)	2.34 (1.75)	13.5 (10.1)	0.33 (0.25)	0.11 (0.08)	64	0.256 (0.420)
Low Altitude - Run 2	0.71 (0.53)	2.27 (1.69)	14.3 (10.6)	0.33 (0.25)	0.11 (0.08)	61	0.257 (0.422)
Low Altitude Average	0.70 (0.52)	2.31 (1.72)	13.9 (10.4)	0.33 (0.25)	0.11 (0.08)	63	0.257 (0.421)
High Altitude - Run 1	1.14 (0.85)	2.68 (2.00)	15.8 (11.8)	0.96 (0.72)	0.16 (0.12)	72	0.267 (0.439)
High Altitude - Run 2	1.43 (1.07)	2.43 (1.81)	14.8 (11.1)	0.69 (0.51)	a	77	0.258 (0.425)
High Altitude Average	1.29 (0.96)	2.56 (1.91)	15.3 (11.4)	0.83 (0.62)	0.16 (0.12)	75	0.263 (0.432)

a Aldehyde sampling failure

Idle emissions of HC, CO, and PM generally increased between 50 and 90 percent at high altitude. Similar to transient test results, emissions of NO_x during idle tests decreased slightly at high altitude. Low altitude and high altitude total aldehydes and percent volatiles at idle were about the same.

High altitude operation at intermediate speed mode increased HC, CO, PM, and total aldehyde emissions by 84, 11, 152, and 45 percent, respectively. Percent volatiles also increased slightly at high altitude. Curiously, for the Caterpillar 3208, the intermediate speed mode was the only condition examined in which NO_x emission levels increased at high altitude. The NO_x emission instrument and calibration were checked, and no problems were identified. The cause for higher levels of NO_x at high altitude is puzzling, and may be attributable to unique characteristics of the engine and test condition. Further examination of NO_x emissions for conditions near this intermediate speed mode would be helpful to identify where and why the shift in NO_x emissions with altitude takes place.

Detailed data for transient and steady-state emissions of HC, CO, NO_x, PM, and BSFC from the Caterpillar 3208 are located in Appendix A. Data for individual aldehydes measured during transient and steady state tests are located in Appendix B.

B. Emission Results from the Cummins NTC-350

Torque maps of the Cummins NTC-350 at both high and low altitude show that torque is approximately 15 to 30 percent lower at high altitude conditions than at low altitude for engine speeds less than 1200 rpm. Both high and low altitude torque maps for the Cummins NTC-350 are given in Figure 7 for reference. Between intermediate and rated speeds, the torque at high altitude conditions was equal to the torque at low altitude. During the mapping procedure, the MVT switches to fully retarded position; therefore, the torque map data are the same for either "malfunction" or normal operation of the MVT system.

One hot-start transient emission test was run at both high and low altitude with the MVT operating properly for reference purposes. In addition, one idle steady state emission test was run at each altitude condition with the variable timing operational. The variable timing system retards injection timing at loads greater than 25 percent, therefore, the intermediate speed with 50 percent load steady-state test results are representative of both "malfunction" and normal MVT operation and were grouped with the "malfunction" configuration runs. Hot-start transient and idle emission results with variable timing operating properly are given in Table 12.

Hot-start emission levels for the Cummins NTC-350 with normally operating MVT were in general agreement with levels expected from this engine when tested at low altitude. With high altitude operation, hot-start transient emissions of HC, CO, PM, percent volatiles, and total aldehydes all increased, while NO_x emissions decreased somewhat. These changes were directionally similar to the changes in regulated emissions for the naturally aspirated Caterpillar 3208 at high altitude, but they were not as large for the turbocharged Cummins NTC-350. Idle emissions of HC, total aldehydes, and CO increased slightly with altitude, but surprisingly, idle NO_x emissions increased and PM emissions decreased with altitude.

Cold-start and hot-start transient emissions from the Cummins NTC-350 with fixed retarded timing for the "malfunction" configuration are presented in Tables 13 and 14. Hot-start emissions for the normal configuration were grossly affected by using the fixed retarded timing malfunction. Low altitude HC, CO, PM, and total aldehydes generally doubled, while NO_x emissions decreased by 26 percent with the malfunction. High altitude severely aggravated "malfunction" configuration hot-start emissions further, causing HC, CO, PM, and total aldehydes to increase by factors of 2 to 3 times over low altitude hot-start levels. Percent volatiles of the hot-start PM emissions also were substantially increased with the "malfunction" and with high altitude. Hot-start transient NO_x emission levels for the "malfunction" configuration decreased slightly at high altitude. Except for NO_x emissions, all

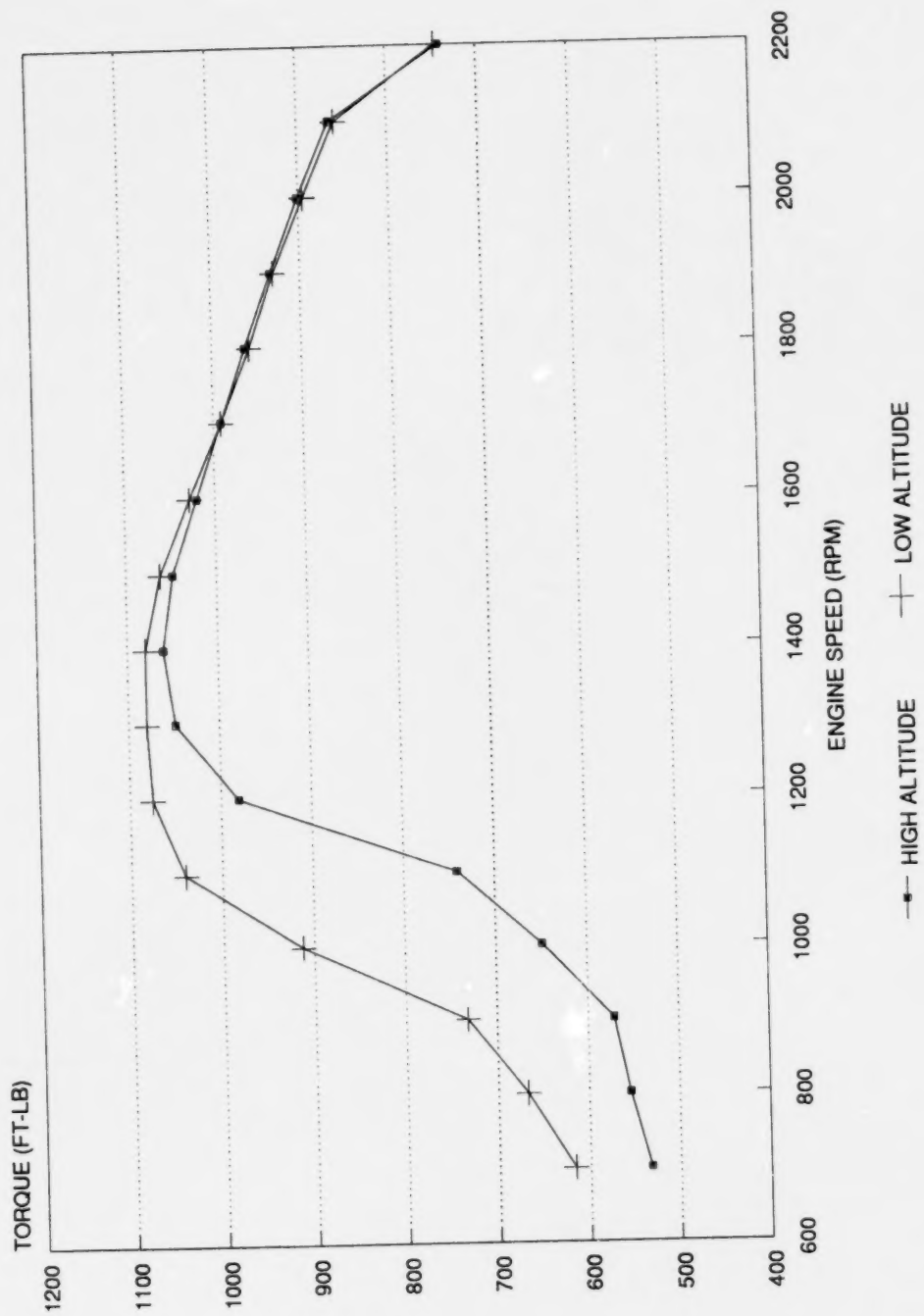


FIGURE 7. TORQUE MAP - CUMMINS NTC-350

TABLE 12. HOT-START TRANSIENT AND IDLE EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CUMMINS NTC-350
WITH VARIABLE TIMING OPERATING NORMALLY

HOT-START TRANSIENT EMISSION RESULTS

TEST DESCRIPTION	HC	CO	g/kw-hr (g/hp-hr)		PM	ALDEHYDES	VOLATILES	BSFC
							% of PM	kg/kw-hr (lb/hp-hr)
Low Altitude	1.28 (0.95)	3.18 (2.37)	6.99 (5.21)	0.63 (0.47)	0.16 (0.12)	6	0.268 (0.440)	
High Altitude	1.53 (1.14)	6.00 (4.47)	6.48 (4.83)	0.92 (0.68)	0.26 (0.19)	12	0.272 (0.448)	

IDLE EMISSION RESULTS

TEST DESCRIPTION	HC	CO	g/hr (g/hr)		PM	ALDEHYDES	VOLATILES	FUEL
							% of PM	kg/hr (lb/hr)
Low Altitude	63.3	39.3	55.2	8.7	7.4	a	< 5	1.65 (3.64)
High Altitude	64.1	44.1	66.1	7.5	6.7	a	< 5	1.92 (4.24)

a Low particulate loadings for this condition limit resolution to 5 %

TABLE 13. COLD-START TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CUMMINS NTC-350
WITH FIXED RETARDED TIMING

TEST DESCRIPTION	HC	CO	NOx g/kw-hr (g/hp-hr)	PM	ALDEHYDES	VOLATILES % of PM	BSFC kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	7.08 (5.28)	6.14 (4.58)	4.70 (3.50)	1.8 (1.3)	0.51 (0.38)	33	0.297 (0.489)
Low Altitude - Run 2	8.01 (5.97)	6.51 (4.85)	4.92 (3.67)	1.9 (1.4)	0.57 (0.43)	31	0.298 (0.489)
Low Altitude Average	7.55 (5.63)	6.33 (4.72)	4.81 (3.59)	1.8 (1.4)	0.54 (0.41)	32	0.298 (0.489)
High Altitude - Run 1	15.0 (11.2)	12.4 (9.2)	4.59 (3.42)	3.9 (2.9)	0.92 (0.69)	38	0.314 (0.517)
High Altitude - Run 2	15.1 (11.3)	12.1 (9.03)	4.69 (3.50)	3.8 (2.8)	0.93 (0.69)	32	0.318 (0.523)
High Altitude Average	15.0 (11.2)	12.2 (9.13)	4.64 (3.46)	3.9 (2.9)	0.93 (0.69)	35	0.316 (0.520)

TABLE 14. HOT-START TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CUMMINS NTC-350
WITH FIXED RETARDED TIMING

TEST DESCRIPTION	HC	CO	NOx g/kw-hr (g/hp-hr)	PM	ALDEHYDES	VOLATILES % of PM	BSFC kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	2.87 (2.14)	5.75 (4.29)	5.07 (3.78)	1.1 (0.85)	0.44 (0.33)	18	0.277 (0.456)
Low Altitude - Run 2	2.82 (2.10)	5.85 (4.36)	5.25 (3.92)	1.1 (0.83)	0.42 (0.31)	11	0.278 (0.457)
Low Altitude Average	2.85 (2.12)	5.80 (4.33)	5.16 (3.85)	1.1 (0.84)	0.43 (0.32)	15	0.278 (0.457)
High Altitude - Run 1	8.83 (6.59)	11.2 (8.39)	4.55 (3.39)	2.7 (2.0)	1.2 (0.91)	24	0.282 (0.463)
High Altitude - Run 2	10.7 (7.99)	11.8 (8.78)	4.66 (3.48)	3.1 (2.3)	a	31	0.290 (0.477)
High Altitude Average	9.78 (7.29)	11.5 (8.59)	4.61 (3.44)	2.9 (2.2)	1.2 (0.91)	28	0.286 (0.470)

a Aldehyde sampling failure

emission levels were higher for cold-start than for hot-start at low altitude. At high altitude, all emissions except NO_x for both cold-start and hot-start transient operation of the Cummins NTC-350 in the "malfunction" configuration were substantially increased, and BSFC also increased.

Composite transient emission results for the Cummins NTC-350 with MVT set to the fixed retarded timing position for the "malfunction" configuration and using high and low altitude conditions are summarized in Table 15. Average composite transient HC emissions at high altitude were triple the levels measured at low altitude. Average high altitude emissions of CO doubled, while PM and total aldehydes were both about 2.5 times the low altitude emission levels. The composite transient emission level of NO_x decreased by about 10 percent from low to high altitude. High altitude increased composite transient BSFC by 3 percent. The composite transient high altitude percentage of volatile PM was approximately 70 percent greater than the low altitude percentage of volatile PM.

Smoke test results are given in Table 16. In the "malfunction" configuration at low altitude, the "A" smoke factor averaged 32 percent opacity, well above the limit of 20 set by EPA. It is interesting to note that even though the "A" factor limit was exceeded in the "malfunction" configuration, the "B" and "C" factors for smoke were still below the EPA limits. It should be noted that the "B" factor, or lugging mode, takes place during established full-rack engine operation, where the Cummins NTC-350 MVT would normally operate in the full retarded position regardless of the presence of a malfunctioning MVT. Similarly, "A" and "C" smoke factors are determined during full-rack operation; however, these engine operations are preceded by idle or light load operation that would normally be run in an advanced timing position with a normally operating MVT system. At high altitude, all three smoke factors deteriorated, especially the "A" and "C" factors.

Steady-state emission results for the Cummins NTC-350 in the "malfunction" configuration are presented in Table 17. Curb idle emissions were taken over a 15 minute test period with the dynamometer adjusted to approximately zero torque. Retard of timing at idle caused HC and total aldehyde emissions to increase by a factor of 5, CO by a factor of 4, and PM by a factor of 6, while NO_x levels were reduced by about 50 percent and fuel usage increased by almost 40 percent. At high altitude, "malfunction" configuration idle emissions of HC, CO, PM, and total aldehydes were dramatically increased while NO_x emissions decreased. "Malfunction" idle emissions of HC, PM, and total aldehyde were all 3 to 4 times greater at high altitude compared to low altitude. Percent volatiles of idle PM increased substantially with "malfunction" and remained high at high altitude. Emissions of CO increased 76 percent and NO_x decreased 27 percent for the idle mode at high altitude compared to low altitude.

Intermediate-speed mode emissions were measured during 15 minutes at 1300 rpm and 730 newton meters (540 foot-pounds) of torque. High altitude operation for the intermediate speed mode increased PM and CO emissions 72 and 128 percent, respectively. Percent volatiles of PM for the intermediate speed mode increased at high altitude to almost 3 times the low altitude levels. At the intermediate speed condition, high altitude HC, NO_x , and total aldehyde emissions were generally equal to those obtained at low altitude.

Detailed data for transient and steady-state emissions of HC, CO, NO_x , PM, and BSFC are located in Appendix C. Data for individual aldehydes measured during transient and steady state tests are located in Appendix D.

TABLE 15. COMPOSITE TRANSIENT EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CUMMINS NTC-350
WITH FIXED RETARDED TIMING

TEST DESCRIPTION	HC	CO	NOx	PM	ALDEHYDES	VOLATILES	BSFC
			g/kw-hr (g/hp-hr)			% of PM	kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	3.47 (2.59)	5.81 (4.33)	5.02 (3.74)	1.2 (0.92)	0.45 (0.34)	20	0.280 (0.461)
Low Altitude - Run 2	3.57 (2.66)	5.94 (4.43)	5.20 (3.88)	1.2 (0.91)	0.44 (0.33)	14	0.281 (0.462)
Low Altitude Average	3.52 (2.63)	5.88 (4.38)	5.11 (3.81)	1.2 (0.92)	0.45 (0.34)	17	0.281 (0.462)
High Altitude - Run 1	9.70 (7.23)	11.4 (8.50)	4.55 (3.40)	2.9 (2.1)	1.2 (0.88)	26	0.286 (0.471)
High Altitude - Run 2	11.3 (8.45)	11.8 (8.81)	4.67 (3.48)	3.2 (2.4)	a	31	0.294 (0.484)
High Altitude Average	10.5 (7.84)	11.6 (8.66)	4.61 (3.44)	3.1 (2.3)	1.2 (0.88)	29	0.290 (0.478)

a Aldehyde sampling failure during hot-start

TABLE 16. SMOKE TEST RESULTS
FROM HIGH ALTITUDE SIMULATION ON CUMMINS NTC-350
WITH FIXED RETARDED TIMING

	Smoke Factor, % Opacity		
	"A"	"B"	"C"
EPA Standards	20	15	50
Low Altitude - Run 1	32	7.6	39
Low Altitude - Run 2	32	7.6	40
Low Altitude Average	32	7.6	40
High Altitude - Run 1	42	10	62
High Altitude - Run 2	36	9.7	56
High Altitude Average	39	10	59

TABLE 17. STEADY-STATE EMISSION RESULTS
FROM HIGH ALTITUDE SIMULATION ON CUMMINS NTC-350
WITH FIXED RETARDED TIMING

IDLE MODE

TEST DESCRIPTION	HC	CO	NOx	PM	ALDEHYDES	VOLATILES	FUEL
			g/hr (g/hr)			% of PM	kg/hr (lb/hr)
Low Altitude - Run 1	299	160	29.8	44	28	50	2.53 (5.56)
Low Altitude - Run 2	292	163	24.2	56	44	48	2.02 (4.48)
Low Altitude Average	296	162	27.0	50	36	49	2.28 (5.02)
High Altitude - Run 1	824	224	16.0	170	98	56	1.98 (4.36)
High Altitude - Run 2	1240	346	23.6	290	120	28	3.32 (7.32)
High Altitude Average	1030	285	19.8	230	110	42	2.65 (5.84)

INTERMEDIATE MODE

TEST DESCRIPTION	HC	CO	NOx	PM	ALDEHYDES	VOLATILES	BSFC
			g/kw-hr (g/hp-hr)			% of PM	kg/kw-hr (lb/hp-hr)
Low Altitude - Run 1	0.52 (0.38)	3.12 (2.33)	5.17 (3.86)	0.84 (0.63)	0.03 (0.02)	4	0.245 (0.403)
Low Altitude - Run 2	0.44 (0.33)	2.77 (2.06)	4.51 (3.36)	0.95 (0.71)	0.04 (0.03)	6	0.241 (0.397)
Low Altitude Average	0.48 (0.36)	2.95 (2.20)	4.84 (3.61)	0.90 (0.67)	0.04 (0.03)	5	0.243 (0.400)
High Altitude - Run 1	0.44 (0.33)	6.88 (5.13)	4.85 (3.61)	1.5 (1.1)	0.07 (0.05)	14	0.247 (0.406)
High Altitude - Run 2	0.42 (0.31)	6.60 (4.92)	4.52 (3.37)	1.6 (1.2)	0.07 (0.05)	13	0.235 (0.386)
High Altitude Average	0.43 (0.32)	6.74 (5.03)	4.69 (3.49)	1.6 (1.2)	0.07 (0.05)	14	0.241 (0.396)

REFERENCES

1. Code of Federal Regulations 40, Part 86, Subpart N, "Emissions Regulations for New Gasoline - and Diesel-Fueled Heavy-Duty Engines; Gaseous Exhaust Test Procedures," July 1, 1988.
2. Code of Federal Regulations 40, Part 86, Subpart I, "Emissions Regulations for New Diesel-Fueled Heavy-Duty Engines; Smoke Exhaust Test Procedures," July 1, 1988.
3. Smith, L.R., "Characterization of Exhaust Emissions from Alcohol-Fueled Vehicles," Final Report to CRC, CAPE-30-81, May 1985.

APPENDIX A

**SEGMENT BY SEGMENT TRANSIENT AND STEADY-STATE
REGULATED EMISSION RESULTS FROM CATERPILLAR 3208**

**TABLE A-1. LOW ALTITUDE COLD-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. LA1 RUN1
DATE 5/16/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 735.08 MM HG(28.94 IN HG)
DRY BULB TEMP. (ENG.) 28.3 DEG C(83.0 DEG F)

RELATIVE HUMIDITY , ENGINE-74. PCT , CVS-76. PCT ENG. DEW PT. 74.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 18.8 GM/KG(131.5 GRAINS/LB) NOX HUMIDITY C.F. 1.1722

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	294.2	303.7	302.7	305.2
TOT. BLOWER RATE SCMM (SCFM)	55.71 (1967.3)	55.73 (1967.8)	55.72 (1967.5)	55.74 (1968.1)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.35)	.04 (1.35)	.04 (1.35)	.04 (1.35)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	273.4 (9654.)	282.3 (9968.)	281.3 (9933.)	283.7 (10019.)
HC SAMPLE METER/RANGE/PPM	18.4/42/ 36.69	16.5/42/ 32.98	14.8/42/ 29.67	7.7/42/ 15.47
HC BCKGRD METER/RANGE/PPM	1.7/42/ 3.40	1.7/42/ 3.40	1.7/42/ 3.40	1.7/42/ 3.40
CO SAMPLE METER/RANGE/PPM	76.8/12/ 76.66	75.4/12/ 75.22	42.4/13/ 98.33	30.9/12/ 30.41
CO BCKGRD METER/RANGE/PPM	.3/12/ .30	.4/12/ .41	.0/13/ .00	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	54.4/14/ .3145	62.7/14/ .4049	94.3/14/ .9781	50.7/14/ .2792
CO2 BCKGRD METER/RANGE/PCT	12.7/14/ .0426	13.3/14/ .0450	14.4/14/ .0494	13.6/14/ .0462
NOX SAMPLE METER/RANGE/PPM	12.4/43/ 30.95	15.6/43/ 38.99	41.5/43/103.81	13.9/43/ 34.79
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30	.5/ 2/ .50	.9/ 2/ .91	.5/ 2/ .50
DILUTION FACTOR	41.15	32.25	13.53	47.24
HC CONCENTRATION PPM	33.37	29.69	26.52	12.14
CO CONCENTRATION PPM	74.02	72.40	94.05	29.49
CO2 CONCENTRATION PCT	.2729	.3613	.9323	.2340
NOX CONCENTRATION PPM	29.66	37.21	98.97	33.18
HC MASS GRAMS	5.261	4.832	4.302	1.986
CO MASS GRAMS	23.560	23.793	30.803	9.742
CO2 MASS GRAMS	1365.03	1865.87	4798.18	1214.50
NOX MASS GRAMS	18.176	23.547	62.415	21.106
FUEL KG (LB)	.446 (.98)	.602 (1.33)	1.526 (3.36)	.388 (.86)
KW HR (HP HR)	1.19 (1.59)	1.80 (2.41)	5.39 (7.23)	1.19 (1.60)
BSHC G/KW HR (G/HP HR)	4.44 (3.31)	2.69 (2.01)	.80 (.59)	1.66 (1.24)
BSCD G/KW HR (G/HP HR)	19.87 (14.82)	13.24 (9.87)	5.71 (4.26)	8.17 (6.09)
BSCD2 G/KW HR (G/HP HR)	1151.28 (858.51)	1038.25 (774.22)	889.97 (663.65)	1017.92 (759.06)
BSNOX G/KW HR (G/HP HR)	15.33 (11.43)	13.10 (9.77)	11.58 (8.63)	17.69 (13.19)
BSFC KG/KW HR (LB/HP HR)	.376 (.618)	.335 (.551)	.283 (.465)	.325 (.535)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.57 (12.83)
BSHC G/KW HR (G/HP HR)	1.71 (1.28) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	9.19 (6.85)
BSCD2 G/KW HR (G/HP HR)	966. (720.)
BSNOX G/KW HR (G/HP HR)	13.09 (9.76) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.310 (.509)

**TABLE A-2. LOW ALTITUDE HOT-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CYS NO. 27

TEST NO. LA 1 RUN1
DATE 5/16/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 734.82 MM HG(28.93 IN HG)
DRY BULB TEMP. (ENG.) 28.3 DEG C(83.0 DEG F)

RELATIVE HUMIDITY, ENGINE-74. PCT, CYS-80. PCT ENG. DEW PT. 74.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 18.8 GM/KG(131.5 GRAINS/LB) NOX HUMIDITY C.F. 1.1723

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	297.7	296.9	305.4	306.1
TOT. BLOWER RATE SCMM (SCFM)	55.66 (1965.3)	55.69 (1966.5)	55.65 (1965.1)	55.99 (1977.1)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.34)	.04 (1.34)	.04 (1.34)	.04 (1.34)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	276.4 (9759.1)	275.9 (9738.1)	283.5 (10010.1)	285.9 (10094.1)
HC SAMPLE METER/RANGE/PPM	17.5/41/ 17.50	24.3/41/ 24.33	27.7/41/ 27.66	17.9/41/ 17.91
HC BCKGRD METER/RANGE/PPM	4.6/41/ 4.60	4.6/41/ 4.60	4.6/41/ 4.60	4.6/41/ 4.60
CO SAMPLE METER/RANGE/PPM	33.8/12/ 33.24	59.3/12/ 58.69	91.5/12/ 91.76	28.8/12/ 28.36
CO BCKGRD METER/RANGE/PPM	.1/12/ .10	.4/12/ .41	.0/12/ .00	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	50.7/14/ .2792	62.7/14/ .4049	34.5/14/ .9836	50.3/14/ .2755
CO2 BCKGRD METER/RANGE/PCT	11.7/14/ .0388	11.8/14/ .0391	13.1/14/ .0442	12.8/14/ .0430
NOX SAMPLE METER/RANGE/PPM	12.6/43/ 31.44	15.9/43/ 33.76	39.7/43/ 99.24	13.3/43/ 33.28
NOX BCKGRD METER/RANGE/PPM	.5/ 2/ .50	.5/ 2/ .50	1.1/ 2/ 1.11	.7/ 2/ .71
DILUTION FACTOR	47.16	32.45	13.47	47.84
HC CONCENTRATION PPM	13.00	19.88	23.41	13.41
CO CONCENTRATION PPM	32.11	56.34	87.65	27.47
CO2 CONCENTRATION PCT	.2412	.3670	.9427	.2334
NOX CONCENTRATION PPM	29.92	27.94	94.35	31.51
HC MASS GRAMS	2.072	3.161	3.826	2.211
CO MASS GRAMS	10.332	18.088	28.928	9.144
CO2 MASS GRAMS	1219.74	1851.39	4889.03	1220.70
NOX MASS GRAMS	18.541	23.459	59.964	20.195
FUEL KG (LB)	.390 (.86)	.593 (1.31)	1.553 (3.42)	.390 (.86)
KW HR (HP HR)	1.16 (1.56)	1.79 (2.40)	5.41 (7.25)	1.17 (1.57)
BSHC G/KW HR (G/HP HR)	1.78 (1.33)	1.77 (1.32)	.71 (.53)	1.89 (1.41)
BSCO G/KW HR (G/HP HR)	8.88 (6.62)	10.11 (7.54)	5.35 (3.99)	7.81 (5.82)
BSC02 G/KW HR (G/HP HR)	1048.52 (781.88)	1034.48 (771.41)	904.32 (674.35)	1042.67 (777.52)
BSNOX G/KW HR (G/HP HR)	15.94 (11.89)	13.11 (9.77)	11.09 (8.27)	17.25 (12.86)
BSFC KG/KW HR (LB/HP HR)	.335 (.551)	.332 (.545)	.287 (.472)	.333 (.548)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.53 (12.78)
BSHC G/KW HR (G/HP HR)	1.18 (.88) (CONTINUOUS)
BSCO G/KW HR (G/HP HR)	6.98 (5.20)
BSC02 G/KW HR (G/HP HR)	963. (718.)
BSNOX G/KW HR (G/HP HR)	12.82 (9.56) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.307 (.505)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	7.341
	G/KWHR(G/HPHR)	.78 (.58)
	G/KG FUEL (G/LB FUEL)	2.38 (1.08)
	FILTER EFF.	95.0

**TABLE A-3. LOW ALTITUDE STEADY-STATE IDLE MODE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. LA1 RUN1
DATE 5/16/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 733.04 MM HG(28.86 IN HG)
DRY BULB TEMP. (ENG.) 32.2 DEG C(90.0 DEG F)

RELATIVE HUMIDITY , ENGINE-56. PCT , CVS-58. PCT ENG. DEW PT. 72.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 17.6 GM/KG(123.0 GRAINS/LB) NOX HUMIDITY C.F. 1.1427

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.2
TOT. BLOWER RATE SCMH (SCFM)	55.76 (1968.7)
TOT. 90MM RATE SCMH (SCFM)	.04 (1.48)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	837.2 (29562.)
HC SAMPLE METER/RANGE/PPM	12.6/41/ 12.60
HC BCKGRD METER/RANGE/PPM	1.8/41/ 1.80
CO SAMPLE METER/RANGE/PPM	18.5/12/ 18.32
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	25.0/14/ .0985
CO2 BCKGRD METER/RANGE/PCT	10.9/14/ .0357
NOX SAMPLE METER/RANGE/PPM	4.6/43/ 11.60
NOX BCKGRD METER/RANGE/PPM	.8/ 1/ .21
DILUTION FACTOR	131.98
HC CONCENTRATION PPM	10.81
CO CONCENTRATION PPM	17.94
CO2 CONCENTRATION PCT	.0630
NOX CONCENTRATION PPM	11.05
HC MASS GRAMS	5.220
CO MASS GRAMS	17.484
CO2 MASS GRAMS	965.14
NOX MASS GRAMS	20.210
FUEL KG (LB)	.317 (.70)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES GRAMS/TEST 1.362

G/KG FUEL (G/LB FUEL) 4.30 (1.95)
FILTER EFF. 75.2

**TABLE A-4. LOW ALTITUDE STEADY-STATE INTERMEDIATE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. LA 1 RUN1
DATE 5/16/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 732.54 MM HG(28.84 IN HG)
DRY BULB TEMP. (ENG.) 33.3 DEG C(92.0 DEG F)

RELATIVE HUMIDITY, ENGINE-S1. PCT, CVS-S5. PCT ENG. DEW PT. 71.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 17.0 GM/KG(118.9 GRAINS/LB) NOX HUMIDITY C.F. 1.1289

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.4
TOT. BLOWER RATE SCMM (SCFM)	55.81 (1970.5)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.47)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	838.2 (29595.)

HC SAMPLE METER/RANGE/PPM	20.8/41/ 20.81
HC BCKGRD METER/RANGE/PPM	3.0/41/ 3.00
CO SAMPLE METER/RANGE/PPM	31.8/12/ 31.29
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	82.2/14/ .6998
CO2 BCKGRD METER/RANGE/PCT	11.2/14/ .0369
NOX SAMPLE METER/RANGE/PPM	39.2/43/ 98.06
NOX BCKGRD METER/RANGE/PPM	.5/ 2/ .50

DILUTION FACTOR	19.01
HC CONCENTRATION PPM	17.97
CO CONCENTRATION PPM	30.30
CO2 CONCENTRATION PCT	.6649
NOX CONCENTRATION PPM	94.35

HC MASS GRAMS	8.685
CO MASS GRAMS	29.570
CO2 MASS GRAMS	10194.44
NOX MASS GRAMS	170.658
FUEL KG (LB)	3.224 (7.11)
KW HR (HP HR)	12.61 (16.91)

BSHC G/KW HR (G/HP HR)	.69 (.51)
BSCD G/KW HR (G/HP HR)	2.34 (1.75)
BSCD2 G/KW HR (G/HP HR)	808.45 (602.86)
BSNOX G/KW HR (G/HP HR)	13.53 (10.09)
BSFC KG/KW HR (LB/HP HR)	.256 (.420)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	12.61 (16.91)
BSHC G/KW HR (G/HP HR)	.69 (.51) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	2.34 (1.75)
BSCD2 G/KW HR (G/HP HR)	808. (603.)
BSNOX G/KW HR (G/HP HR)	13.53 (10.09) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.256 (.420)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	4.204
	G/KWHR(G/HPHR)	.33 (.25)
	G/KG FUEL (G/LB FUEL)	1.30 (.59)
	FILTER EFF.	86.2

**TABLE A-5. LOW ALTITUDE COLD-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. LA 2 RUN1
DATE 5/17/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 732.28 MM HG(28.83 IN HG)
DRY BULB TEMP. (ENG.) 26.1 DEG C(79.0 DEG F)

RELATIVE HUMIDITY , ENGINE-85. PCT , CVS-87. PCT ENG. DEW PT. 74.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 18.9 GM/KG(132.0 GRAINS/LB) NOX HUMIDITY C.F. 1.1740

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	299.6	297.3	304.3	312.2
TOT. BLOWER RATE SCMM (SCFM)	55.17 (1948.2)	55.46 (1958.2)	55.47 (1958.7)	55.66 (1965.4)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.45)	.04 (1.45)	.04 (1.45)	.04 (1.45)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	275.7 (9736.)	275.0 (9711.)	281.6 (9942.)	289.9 (10235.)
HC SAMPLE METER/RANGE/PPM	21.8/42/ 43.61	18.4/42/ 36.79	14.4/42/ 28.75	5.4/42/ 10.88
HC BCKGRD METER/RANGE/PPM	3.3/42/ 6.60	3.3/42/ 6.60	3.3/42/ 6.60	3.3/42/ 6.60
CO SAMPLE METER/RANGE/PPM	88.2/12/ 88.39	76.0/12/ 75.84	41.7/13/ 96.64	32.0/12/ 31.48
CO BCKGRD METER/RANGE/PPM	.1/12/ .10	.2/12/ .20	.0/13/ .00	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	54.9/14/ .3195	61.5/14/ .3908	96.6/14/ .7894	50.6/14/ .2783
CO2 BCKGRD METER/RANGE/PCT	11.6/14/ .0384	12.0/14/ .0399	11.8/14/ .0391	12.0/14/ .0399
NOX SAMPLE METER/RANGE/PPM	12.4/43/ 31.12	16.2/43/ 40.56	41.3/43/103.26	14.0/43/ 35.05
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30	.5/ 2/ .50	.6/ 2/ .60	.5/ 2/ .50
DILUTION FACTOR	40.31	33.35	16.72	47.45
HC CONCENTRATION PPM	37.18	30.39	22.55	4.42
CO CONCENTRATION PPM	85.26	72.94	92.45	30.42
CO2 CONCENTRATION PCT	.2821	.3521	.7526	.2392
NOX CONCENTRATION PPM	29.77	38.68	98.77	33.39
HC MASS GRAMS	5.911	4.819	3.661	.739
CO MASS GRAMS	27.368	23.352	30.302	10.267
CO2 MASS GRAMS	1422.83	1771.31	3876.63	1268.41
NOX MASS GRAMS	18.431	23.882	62.436	21.729
FUEL KG (LB)	.466 (1.03)	.573 (1.26)	1.236 (2.72)	.404 (.89)
KW HR (HP HR)	1.19 (1.59)	1.79 (2.40)	5.38 (7.22)	1.21 (1.62)
BSHC G/KW HR (G/HP HR)	4.99 (3.72)	2.69 (2.01)	.68 (.51)	.61 (.46)
BSCD G/KW HR (G/HP HR)	23.08 (17.21)	13.05 (9.73)	5.63 (4.20)	8.50 (6.34)
BSCD2 G/KW HR (G/HP HR)	1200.03 (894.86)	989.74 (738.05)	720.03 (536.93)	1049.98 (782.97)
BSNOX G/KW HR (G/HP HR)	15.55 (11.59)	13.34 (9.95)	11.60 (8.65)	17.99 (13.41)
BSFC KG/KW HR (LB/HP HR)	.393 (.646)	.320 (.526)	.230 (.377)	.335 (.550)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.57 (12.83)
BSHC G/KW HR (G/HP HR)	1.58 (1.18) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	9.54 (7.12)
BSCD2 G/KW HR (G/HP HR)	872. (650.)
BSNOX G/KW HR (G/HP HR)	13.22 (9.86) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.280 (.460)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	8.419
	G/KWHR(G/HPHR)	.89 (.67)
	G/KG FUEL (G/LB FUEL)	2.61 (1.19)
	FILTER EFF.	90.4

**TABLE A-6. LOW ALTITUDE HOT-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2**

ENGINE NO.
ENGINE MODEL / CATERPIL 3208A
ENGINE 10.4 L(636, CID) V-8
CVS NO. 27

TEST NO. LA 2 RUN1
DATE 5/17/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 733.81 MM HG(28.89 IN HG)
DRY BULB TEMP. (ENG.) 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY, ENGINE-76. PCT, CVS-79. PCT ENG. DEW PT. 70.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 16.4 GM/KG(114.6 GRAINS/LB) NOX HUMIDITY C.F. 1.1148

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	297.5	299.6	307.0	308.7
TOT. BLOWER RATE SCMM (SCFM)	55.20 (1949.2)	55.48 (1959.0)	55.44 (1957.5)	55.44 (1957.6)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.43)	.04 (1.43)	.04 (1.43)	.04 (1.43)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	273.9 (9673.)	277.2 (9790.)	283.9 (10024.)	285.5 (10080.)
HC SAMPLE METER/RANGE/PPM	16.9/41/ 16.88	24.0/41/ 23.97	27.0/41/ 26.96	15.1/41/ 15.11
HC BCKGRD METER/RANGE/PPM	5.0/41/ 5.00	5.0/41/ 5.00	5.0/41/ 5.00	5.0/41/ 5.00
CO SAMPLE METER/RANGE/PPM	35.6/12/ 35.01	61.1/12/ 60.52	89.4/12/ 89.62	30.4/12/ 29.92
CO BCKGRD METER/RANGE/PPM	.0/12/ .00	.2/12/ .20	.5/12/ .51	.5/12/ .51
CO2 SAMPLE METER/RANGE/PCT	53.0/14/ .3008	54.0/14/ .4206	94.2/14/ .9753	51.4/14/ .2857
CO2 BCKGRD METER/RANGE/PCT	15.4/14/ .0535	14.3/14/ .0490	14.6/14/ .0502	14.4/14/ .0494
NOX SAMPLE METER/RANGE/PPM	13.3/43/ 33.27	16.6/43/ 41.45	42.4/43/105.87	13.9/43/ 34.86
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ .80	.7/ 2/ .71	1.0/ 2/ 1.01	.8/ 2/ .81
DILUTION FACTOR	43.81	31.25	13.58	46.20
HC CONCENTRATION PPM	12.00	19.13	22.33	10.22
CO CONCENTRATION PPM	33.92	58.30	85.20	28.51
CO2 CONCENTRATION PCT	.2485	.3732	.9288	.2373
NOX CONCENTRATION PPM	31.73	39.53	101.25	33.08
HC MASS GRAMS	1.896	3.059	3.655	1.682
CO MASS GRAMS	10.816	18.818	28.156	9.474
CO2 MASS GRAMS	1245.33	1892.74	4823.38	1239.35
NOX MASS GRAMS	18.530	23.367	61.276	20.134
FUEL KG (LB)	.398 (.88)	.607 (1.34)	1.532 (3.38)	.396 (.87)
KW HR (HP HR)	1.16 (1.56)	1.79 (2.40)	5.42 (7.27)	1.17 (1.57)
BSHC G/KW HR (G/HP HR)	1.63 (1.22)	1.71 (1.27)	.67 (.50)	1.44 (1.07)
BSCD G/KW HR (G/HP HR)	9.30 (6.93)	10.51 (7.84)	5.19 (3.87)	8.09 (6.03)
BSCD2 G/KW HR (G/HP HR)	1070.52 (798.29)	1057.58 (788.64)	889.72 (663.46)	1058.60 (789.39)
BSNOX G/KW HR (G/HP HR)	15.93 (11.88)	13.06 (9.74)	11.30 (8.43)	17.20 (12.82)
BSFC KG/KW HR (LB/HP HR)	.342 (.563)	.339 (.557)	.283 (.465)	.338 (.555)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.54 (12.80)
BSHC G/KW HR (G/HP HR)	1.08 (.80) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	7.05 (5.25)
BSCD2 G/KW HR (G/HP HR)	964. (719.)
BSNOX G/KW HR (G/HP HR)	12.92 (9.63) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.307 (.505)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	7.720
	G/KWHR(G/HPHR)	.82 (.62)
	G/KG FUEL (G/LB FUEL)	2.48 (1.12)
	FILTER EFF.	94.5

**TABLE A-7. LOW ALTITUDE STEADY-STATE IDLE MODE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. LA 2 RUN1
DATE 5/17/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 732.54 MM HG(28.84 IN HG)
DRY BULB TEMP. (ENG.) 26.7 DEG C(80.0 DEG F)

RELATIVE HUMIDITY, ENGINE-69. PCT, CVS-68. PCT ENG. DEW PT. 69.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 15.8 GM/KG(110.9 GRAINS/LB) NOX HUMIDITY C.F. 1.1028

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.4
TOT. BLOWER RATE SCMM (SCFM)	55.73 (1968.0)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.44)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	837.0 (29556.)

HC SAMPLE METER/RANGE/PPM	13.4/41/ 13.35
HC BCKGRD METER/RANGE/PPM	1.4/41/ 1.40
CO SAMPLE METER/RANGE/PPM	20.5/12/ 20.27
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	57.8/12/ .1135
CO2 BCKGRD METER/RANGE/PCT	29.1/12/ .0476
NOX SAMPLE METER/RANGE/PPM	4.8/43/ 11.99
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .13

DILUTION FACTOR	114.73
HC CONCENTRATION PPM	11.96
CO CONCENTRATION PPM	19.78
CO2 CONCENTRATION PCT	.0663
NOX CONCENTRATION PPM	11.55

HC MASS GRAMS	5.772
CO MASS GRAMS	19.273
CO2 MASS GRAMS	1015.88
NOX MASS GRAMS	20.393
FUEL KG (LB)	.334 (.74)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS
BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	1.223
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G/KG FUEL (G/LB FUEL)	3.66 (1.66)
FILTER EFF.	74.9

**TABLE A-8. LOW ALTITUDE STEADY-STATE INTERMEDIATE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. LA 2 RUN1
DATE 5/17/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 733.30 MM HG(28.87 IN HG)
DRY BULB TEMP. (ENG.) 28.3 DEG C(83.0 DEG F)

RELATIVE HUMIDITY, ENGINE-65. PCT, CVS-79. PCT ENG. DEW PT. 70.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 16.4 GM/KG(114.7 GRAINS/LB) NOX HUMIDITY C.F. 1.1151

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.6
TOT. BLOWER RATE SCMH (SCFM)	55.63 (1964.4)
TOT. 90MM RATE SCMH (SCFM)	.04 (1.43)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	835.7 (29509.)

HC SAMPLE METER/RANGE/PPM	20.2/41/ 20.18
HC BCKGRD METER/RANGE/PPM	1.7/41/ 1.70
CO SAMPLE METER/RANGE/PPM	31.1/12/ 30.60
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	82.6/14/ .7075
CO2 BCKGRD METER/RANGE/PCT	11.9/14/ .0395
NOX SAMPLE METER/RANGE/PPM	42.0/43/104.91
NOX BCKGRD METER/RANGE/PPM	.2/ 3/ .50

DILUTION FACTOR	18.81
HC CONCENTRATION PPM	18.57
CO CONCENTRATION PPM	29.41
CO2 CONCENTRATION PCT	.6701
NOX CONCENTRATION PPM	101.04

HC MASS GRAMS	8.951
CO MASS GRAMS	28.609
CO2 MASS GRAMS	10244.16
NOX MASS GRAMS	180.064
FUEL KG (LB)	3.240 (7.14)
KW HR (HP HR)	12.62 (16.92)

BSHC G/KW HR (G/HP HR)	.71 (.53)
BSCO G/KW HR (G/HP HR)	2.27 (1.69)
BSCO2 G/KW HR (G/HP HR)	811.92 (605.45)
BSNOX G/KW HR (G/HP HR)	14.27 (10.64)
BSFC KG/KW HR (LB/HP HR)	.257 (.422)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	12.62 (16.92)	
BSHC G/KW HR (G/HP HR)	.71 (.53)	(CONTINUOUS)
BSCO G/KW HR (G/HP HR)	2.27 (1.69)	
BSCO2 G/KW HR (G/HP HR)	812. (605.)	
BSNOX G/KW HR (G/HP HR)	14.27 (10.64)	(CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.257 (.422)	

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	4.220
	G/KWHR(G/HPHR)	.33 (.25)
	G/KG FUEL (G/LB FUEL)	1.30 (.59)
	FILTER EFF.	94.5

**TABLE A-9. HIGH ALTITUDE COLD-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. HA 1 RUN1
DATE 5/25/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 735.08 MM HG(28.94 IN HG)
DRY BULB TEMP. (ENG.) 26.7 DEG C(80.0 DEG F)

RELATIVE HUMIDITY, ENGINE-74. PCT, CVS-59. PCT ENG. DEW PT. 71.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 16.9 GM/KG(118.5 GRAINS/LB) NOX HUMIDITY C.F. 1.1275

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.2	299.7	305.3	311.3
TOT. BLOWER RATE SCMM (SCFM)	57.72 (2038.2)	56.78 (2005.0)	56.56 (1997.0)	56.02 (1977.9)
TOT. 90MM RATE SCMM (SCFM)	.02 (.75)	.02 (.75)	.02 (.75)	.02 (.75)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	285.1 (10066.)	283.8 (10019.)	287.9 (10166.)	290.8 (10267.)
HC SAMPLE METER/RANGE/PPM	56.0/42/111.84	51.2/42/102.37	27.8/42/ 55.62	27.0/42/ 53.99
HC BCKGRD METER/RANGE/PPM	3.8/42/ 7.60	3.8/42/ 7.60	3.8/42/ 7.60	3.8/42/ 7.60
CO SAMPLE METER/RANGE/PPM	50.5/14/224.62	73.7/13/177.26	64.4/14/298.27	48.5/13/113.14
CO BCKGRD METER/RANGE/PPM	.2/14/ .81	.1/13/ .23	.1/14/ .40	.0/13/ .00
CO2 SAMPLE METER/RANGE/PCT	82.5/13/ .3379	95.6/13/ .4433	56.8/ 1/1.0419	73.1/13/ .2752
CO2 BCKGRD METER/RANGE/PCT	16.0/13/ .0364	16.2/13/ .0369	2.2/ 1/ .0388	16.0/13/ .0364
NOX SAMPLE METER/RANGE/PPM	8.8/43/ 21.99	12.1/43/ 30.26	39.2/43/ 97.97	11.5/43/ 28.79
NOX BCKGRD METER/RANGE/PPM	1.4/ 1/ .37	.2/ 2/ .20	.5/ 2/ .50	.2/ 2/ .20
DILUTION FACTOR	36.12	28.47	12.45	45.95
HC CONCENTRATION PPM	*****	95.05	48.64	46.56
CO CONCENTRATION PPM	218.08	172.13	286.19	110.37
CO2 CONCENTRATION PCT	.3025	.4077	1.0062	.2396
NOX CONCENTRATION PPM	21.03	29.21	94.17	27.82
HC MASS GRAMS	17.171	15.551	8.074	7.807
CO MASS GRAMS	72.377	56.861	95.924	37.358
CO2 MASS GRAMS	1577.84	2116.14	5299.75	1274.51
NOX MASS GRAMS	12.926	17.869	58.458	17.438
FUEL KG (LB)	.548 (1.21)	.708 (1.56)	1.720 (3.79)	.426 (.94)
KW HR (HP HR)	.97 (1.30)	1.65 (2.21)	5.29 (7.09)	1.14 (1.53)
BSHC G/KW HR (G/HP HR)	17.71 (13.21)	9.44 (7.04)	1.53 (1.14)	6.84 (5.10)
BSCD G/KW HR (G/HP HR)	74.66 (55.67)	34.50 (25.73)	18.14 (13.53)	32.74 (24.42)
BSCD2 G/KW HR (G/HP HR)	1627.63 (1213.72)	1284.07 (957.53)	1002.41 (747.50)	1117.09 (833.02)
BSNOX G/KW HR (G/HP HR)	13.33 (9.94)	10.84 (8.09)	11.06 (8.25)	15.28 (11.40)
BSFC KG/KW HR (LB/HP HR)	.566 (.930)	.430 (.706)	.325 (.535)	.374 (.614)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.05 (12.13)
BSHC G/KW HR (G/HP HR)	5.37 (4.01) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	29.02 (21.64)
BSCD2 G/KW HR (G/HP HR)	1135. (847.)
BSNOX G/KW HR (G/HP HR)	11.80 (8.80) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.376 (.618)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	18.724
	G/KWHR(G/HPHR)	2.07 (1.54)
	G/KG FUEL (G/LB FUEL)	5.50 (2.50)
	FILTER EFF.	93.0

**TABLE A-10. HIGH ALTITUDE HOT-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. HA 1 RUN1
DATE 5/25/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 760.22 MM HG(29.93 IN HG)
DRY BULB TEMP. (ENG.) 27.2 DEG C(81.0 DEG F)

RELATIVE HUMIDITY , ENGINE-62. PCT , CVS-53. PCT ENG. DEW PT. 66.8 DEG F
ABSOLUTE HUMIDITY (ENG.) 14.1 GM/KG(98.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0658

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAJ	NYNF
TIME SECONDS	296.7	300.2	301.6	311.0
TOT. BLOWER RATE SCMM (SCFM)	57.32 (2023.9)	56.51 (1995.5)	56.02 (1977.9)	56.47 (1994.1)
TOT. 90MM RATE SCMM (SCFM)	.02 (.69)	.02 (.69)	.02 (.69)	.02 (.69)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CO. METRES(SCF)	283.5 (10012.)	282.9 (9988.)	281.7 (9946.)	282.8 (10340.)
HC SAMPLE METER/RANGE/PPM	30.9/42/ 61.70	42.9/42/ 85.71	28.6/42/ 57.26	28.1/42/ 56.18
HC BCKGRD METER/RANGE/PPM	2.2/42/ 4.40	2.2/42/ 4.40	2.2/42/ 4.40	2.2/42/ 4.40
CO SAMPLE METER/RANGE/PPM	69.9/13/167.27	62.1/14/285.69	83.1/14/404.90	65.8/13/156.62
CO BCKGRD METER/RANGE/PPM	.3/13/ .69	.1/14/ .40	.3/14/ 1.21	.2/13/ .46
CO2 SAMPLE METER/RANGE/PCT	52.6/14/ .2970	65.3/14/ .4368	60.5/ 1/1.1111	74.8/13/ .2859
CO2 BCKGRD METER/RANGE/PCT	10.9/14/ .0357	11.0/14/ .0361	2.3/ 1/ .0406	16.2/13/ .0369
NOX SAMPLE METER/RANGE/PPM	11.2/43/ 28.02	13.6/43/ 33.93	38.2/43/ 95.59	11.3/43/ 28.24
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30	.3/ 2/ .30	.5/ 2/ .50	.2/ 2/ .20
DILUTION FACTOR	41.94	28.32	11.59	43.68
HC CONCENTRATION PPM	57.40	81.47	53.24	51.88
CO CONCENTRATION PPM	162.79	278.00	388.19	152.63
CO2 CONCENTRATION PCT	.2621	.4020	1.0740	.2498
NOX CONCENTRATION PPM	27.04	32.76	92.07	27.35
HC MASS GRAMS	3.385	13.289	8.648	8.760
CO MASS GRAMS	53.735	91.549	127.302	52.035
CO2 MASS GRAMS	1359.54	2080.09	5534.81	1338.31
NOX MASS GRAMS	15.628	18.891	52.862	16.326
FUEL KG (LB)	.463 (1.02)	.712 (1.57)	1.809 (3.99)	.455 (1.00)
KW HR (HP HR)	1.15 (1.54)	1.72 (2.30)	5.22 (7.00)	1.14 (1.53)
BSHC G/KW HR (G/HP HR)	8.17 (6.09)	7.75 (5.78)	1.66 (1.24)	7.68 (5.73)
BSCD G/KW HR (G/HP HR)	46.79 (34.89)	53.38 (39.80)	24.39 (18.19)	45.61 (34.01)
BSCD2 G/KW HR (G/HP HR)	1183.88 (882.82)	1212.80 (904.39)	1060.33 (790.69)	1173.01 (874.71)
BSNOX G/KW HR (G/HP HR)	13.61 (10.15)	11.01 (8.21)	10.13 (7.55)	14.31 (10.67)
BSFC KG/KW HR (LB/HP HR)	.403 (.663)	.415 (.682)	.347 (.570)	.399 (.655)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.22 (12.37)
BSHC G/KW HR (G/HP HR)	4.35 (3.24) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	35.19 (26.24)
BSCD2 G/KW HR (G/HP HR)	1118. (834.)
BSNOX G/KW HR (G/HP HR)	11.24 (8.38) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.373 (.613)

**PARTICULATE RESULTS, TOTAL FOR 4 BAGS
BOTH FILTERS USED FOR PARTICULATE
90MM PARTICULATE RATES**

GRAMS/TEST	16.250
G/KWHR(G/HPHR)	1.76 (1.31)
G/KG FUEL (G/LB FUEL)	4.73 (2.14)
FILTER EFF.	93.6

TABLE A-11. HIGH ALTITUDE STEADY-STATE IDLE MODE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. HA 1 RUN1
DATE 5/24/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 735.33 MM HG(28.95 IN HG)
DRY BULB TEMP. (ENG.) 27.8 DEG C(82.0 DEG F)

RELATIVE HUMIDITY , ENGINE-63. PCT , CVS-54. PCT ENG. DEW PT. 68.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 15.2 GM/KG(106.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0895

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.0
TOT. BLOWER RATE SCMM (SCFM)	57.89 (2044.0)
TOT. 90MM RATE SCMM (SCFM)	.02 (.74)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	868.7 (30674.)

HC SAMPLE METER/RANGE/PPM	23.9/41/ 23.91
HC BCKGRD METER/RANGE/PPM	~~13.8/41/ 13.89~~ 5.63 ²⁰¹⁴
CO SAMPLE METER/RANGE/PPM	29.8/12/ 29.33
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	23.6/14/ .0913
CO2 BCKGRD METER/RANGE/PCT	10.7/14/ .0350
NOX SAMPLE METER/RANGE/PPM	3.8/43/ 9.40
NOX BCKGRD METER/RANGE/PPM	.6/ 1/ .16

DILUTION FACTOR	138.78
HC CONCENTRATION PPM	10.11
CO CONCENTRATION PPM	28.77
CO2 CONCENTRATION PCT	.0566
NOX CONCENTRATION PPM	9.01

HC MASS GRAMS	~~5.066~~ 9.24 ²⁰¹⁴
CO MASS GRAMS	29.093
CO2 MASS GRAMS	898.70
NOX MASS GRAMS	16.308
FUEL KG (LB)	.302 (.66)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	1.886
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G/KG FUEL (G/LB FUEL)	6.25 (2.84)
FILTER EFF.	73.0

TABLE A-12. HIGH ALTITUDE STEADY-STATE INTERMEDIATE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 1

ENGINE NO.	TEST NO. HA 1	RUN1
ENGINE MODEL 0 CATERPIL 3208A	DATE 5/24/89	
ENGINE 10.4 L(636. CID) V-8	TIME	DIESEL EM-834-F
CVS NO. 27	DYNO NO. 4	BAG CART NO. 2

BAROMETER 735.84 MM HG(28.97 IN HG) RELATIVE HUMIDITY, ENGINE-67. PCT, CVS-52. PCT ENG. DEW PT. 70.0 DEG F
 DRY BULB TEMP. (ENG.) 27.8 DEG C(82.0 DEG F) ABSOLUTE HUMIDITY (ENG.) 16.3 GM/KG(114.3 GRAINS/LB) NOX HUMIDITY C.F. 1.1138

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.0
TOT. BLOWER RATE SCMM (SCFM)	59.35 (2095.7)
TOT. 90MM RATE SCMM (SCFM)	.03 (.88)
TOT. 20x20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	890.7 (31452.)
HC SAMPLE METER/RANGE/PPM	33.4/41/ 33.36
HC BCKGRD METER/RANGE/PPM	6.3/41/ 6.30
CO SAMPLE METER/RANGE/PPM	33.3/12/ 32.75
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	80.6/14/ .6698
CO2 BCKGRD METER/RANGE/PCT	11.2/14/ .0369
NOX SAMPLE METER/RANGE/PPM	42.6/43/106.58
NOX BCKGRD METER/RANGE/PPM	.5/ 3/ 1.25
DILUTION FACTOR	19.81
HC CONCENTRATION PPM	27.38
CO CONCENTRATION PPM	31.78
CO2 CONCENTRATION PCT	.6348
NOX CONCENTRATION PPM	102.04
HC MASS GRAMS	14.062
CO MASS GRAMS	32.951
CO2 MASS GRAMS	10344.13
NOX MASS GRAMS	193.591
FUEL KG (LB)	3.278 (7.23)
KW HR (HP HR)	12.28 (16.47)
BSHC G/KW HR (G/HP HR)	1.14 (.85)
BSCO G/KW HR (G/HP HR)	2.68 (2.00)
BSCD2 G/KW HR (G/HP HR)	842.24 (628.06)
BSNOX G/KW HR (G/HP HR)	15.76 (11.75)
BSFC KG/KW HR (LB/HP HR)	.267 (.439)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	12.28 (16.47)
BSHC G/KW HR (G/HP HR)	1.14 (.85) (CONTINUOUS)
BSCO G/KW HR (G/HP HR)	2.68 (2.00)
BSCD2 G/KW HR (G/HP HR)	842. (628.)
BSNOX G/KW HR (G/HP HR)	15.76 (11.75) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.267 (.439)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS
 BOTH FILTERS USED FOR PARTICULATE
 90MM PARTICULATE RATES GRAMS/TEST 11.823
 G/KWHR(G/HPHR) .96 (.72)
 G/KG FUEL (G/LB FUEL) 3.61 (1.64)
 FILTER EFF. 92.7

**TABLE A-13. HIGH ALTITUDE COLD-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636, CID) V-8
CVS NO. 27

TEST NO. HA 2 RUN1
DATE 5/26/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 737.62 MM HG(29.04 IN HG)
DWY BULB TEMP. (ENG.) 27.2 DEG C(81.0 DEG F)

RELATIVE HUMIDITY, ENGINE-63. PCT, CVS-51. PCT ENG. DEW PT. 67.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 14.7 GM/KG(102.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0773

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	301.2	304.9	311.3
TOT. BLOWER RATE SCFM (SCFM)	58.06 (2050.0)	57.13 (2017.3)	57.02 (2013.2)	56.99 (2012.2)
TOT. 90MM RATE SCFM (SCFM)	.02 (.76)	.02 (.76)	.02 (.76)	.02 (.76)
TOT. 20X20 RATE SCFM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	286.5 (10117.)	286.9 (10131.)	289.8 (10234.)	295.8 (10444.)
HC SAMPLE METER/RANGE/PPM	60.4/42/120.77	58.8/42/117.53	40.8/42/ 81.56	40.0/42/ 79.88
HC BOXGRD METER/RANGE/PPM	5.2/42/ 10.39	5.2/42/ 10.39	5.2/42/ 10.39	5.2/42/ 10.39
CO SAMPLE METER/RANGE/PPM	65.1/13/154.82	67.0/13/159.73	58.3/14/265.25	41.6/13/ 96.40
CO BOXGRD METER/RANGE/PPM	.0/13/ .00	.2/13/ .46	.0/14/ .00	.0/13/ .00
CO2 SAMPLE METER/RANGE/PCT	81.2/13/ .3287	65.8/14/ .4431	96.4/14/1.0385	70.8/13/ .2612
CO2 BOXGRD METER/RANGE/PCT	15.8/13/ .0359	10.9/14/ .0357	11.0/14/ .0361	16.1/13/ .0366
NOX SAMPLE METER/RANGE/PPM	91.5/ 1/ 22.86	29.1/ 2/ 29.15	83.0/ 2/ 82.99	23.8/ 2/ 23.86
NOX BOXGRD METER/RANGE/PPM	.0/ 1/ .00	.2/ 2/ .20	.5/ 2/ .50	.1/ 2/ .10
DILUTION FACTOR	37.65	28.48	12.50	48.10
HC CONCENTRATION PPM	****	****	72.00	69.71
CO CONCENTRATION PPM	151.27	155.27	255.53	94.31
CO2 CONCENTRATION PCT	.2938	.4087	1.0052	.2253
NOX CONCENTRATION PPM	22.86	28.95	82.53	23.76
HC MASS GRAMS	18.281	17.786	12.033	11.888
CO MASS GRAMS	50.457	51.864	86.224	32.475
CO2 MASS GRAMS	1539.82	2144.98	5330.18	1219.14
NOX MASS GRAMS	13.492	17.115	49.277	14.479
FUEL KG (LB)	.527 (1.16)	.717 (1.58)	1.728 (3.81)	.411 (.91)
KW HR (HP HR)	1.16 (1.55)	1.72 (2.30)	5.29 (7.10)	1.16 (1.55)
BSHC G/KW HR (G/HP HR)	15.82 (11.79)	10.37 (7.73)	2.27 (1.69)	10.29 (7.67)
BSCO G/KW HR (G/HP HR)	43.65 (32.55)	30.24 (22.55)	16.29 (12.14)	28.10 (20.95)
BSCO2 G/KW HR (G/HP HR)	1332.21 (993.43)	1250.64 (932.60)	1006.75 (750.73)	1054.77 (786.55)
BSNOX G/KW HR (G/HP HR)	11.67 (8.70)	9.98 (7.44)	9.31 (6.94)	12.53 (9.34)
BSFC KG/KW HR (LB/HP HR)	.456 (.749)	.418 (.687)	.326 (.537)	.355 (.584)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.32 (12.50)
BSHC G/KW HR (G/HP HR)	6.44 (4.80) (CONTINUOUS)
BSCO G/KW HR (G/HP HR)	23.71 (17.68)
BSCO2 G/KW HR (G/HP HR)	1098. (819.)
BSNOX G/KW HR (G/HP HR)	10.12 (7.55) BAG
BSFC KG/KW HR (LB/HP HR)	.363 (.597)

**PARTICULATE RESULTS, TOTAL FOR 4 BAGS
BOTH FILTERS USED FOR PARTICULATE
90MM PARTICULATE RATES**

GRAMS/TEST	14.430
G/KWHR(G/HPHR)	1.55 (1.15)
G/KG FUEL (G/LB FUEL)	4.27 (1.93)
FILTER EFF.	91.5

**TABLE A-14. HIGH ALTITUDE HOT-START TRANSIENT EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2**

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. HA 2 RUN1
DATE 5/26/89
TIME
DYNO NO. 4

DI' SEL EM-834-F
BAG CART NO. 2

BAROMETER 737.36 MM HG(29.03 IN HG)
DRY BULB TEMP. (ENG.) 30.0 DEG C(86.0 DEG F)

RELATIVE HUMIDITY, ENGINE-56. PCT, CVS-46. PCT ENG. DEW PT. 68.5 DEG F
ABSOLUTE HUMIDITY (ENG.) 15.5 GM/KG(108.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0945

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LANF	NYNF
TIME SECONDS	297.0	300.1	304.9	311.4
TOT. BLOWER RATE SCFM (SCFM)	57.99 (2047.7)	56.95 (2010.8)	56.97 (2011.6)	56.60 (1998.5)
TOT. 90MM RATE SCFM (SCFM)	.02 (.73)	.02 (.73)	.02 (.73)	.02 (.73)
TOT. 20X10 RATE SCFM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	287.2 (10140.)	284.9 (10061.)	289.6 (10226.)	293.9 (10376.)
HC SAMPLE METER/RANGE/PPM	39.3/42/ 78.59	50.9/42/101.76	41.8/42/ 83.54	40.2/42/ 80.32
HC BCKGRD METER/RANGE/PPM	5.0/42/ 9.99	5.0/42/ 9.99	5.0/42/ 9.99	5.0/42/ 9.99
CO SAMPLE METER/RANGE/PPM	48.3/13/112.65	69.0/13/164.92	93.0/13/229.75	45.4/13/105.58
CO BCKGRD METER/RANGE/PPM	.0/13/ .00	.1/13/ .23	.1/13/ .23	.3/13/ .69
CO2 SAMPLE METER/RANGE/PCT	73.9/13/ .2802	73.9/13/ .2802	95.5/14/1.0120	50.1/14/ .2737
CO2 BCKGRD METER/RANGE/PCT	15.8/13/ .0359	15.9/13/ .0361	11.0/14/ .0361	10.9/14/ .0357
NOX SAMPLE METER/RANGE/PPM	11.4/43/ 28.48	14.2/43/ 35.38	38.7/43/ 96.68	11.6/43/ 29.01
NOX BCKGRD METER/RANGE/PPM	.0/ 2/ .00	.1/ 2/ .10	.5/ 2/ .50	.1/ 2/ .10
DILUTION FACTOR	44.80	43.72	12.85	45.88
HC CONCENTRATION PPM	68.82	91.99	74.33	70.54
CO CONCENTRATION PPM	110.38	161.39	221.68	102.81
CO2 CONCENTRATION PCT	.2451	.2449	.9787	.2388
NOX CONCENTRATION PPM	27.72	34.34	92.99	28.14
HC MASS GRAMS	11.395	15.114	12.412	11.953
CO MASS GRAMS	36.901	53.535	74.740	35.170
CO2 MASS GRAMS	1287.73	1276.56	5185.43	1283.54
NOX MASS GRAMS	16.661	20.481	56.366	17.309
FUEL KG (LB)	.434 (.96)	.442 (.98)	1.678 (3.70)	.432 (.95)
KW HR (HP HR)	1.16 (1.56)	1.74 (2.34)	5.29 (7.09)	1.15 (1.54)
BSHC G/KW HR (G/HP HR)	9.80 (7.30)	8.66 (6.46)	2.35 (1.75)	10.41 (7.76)
BSCD G/KW HR (G/HP HR)	31.72 (23.65)	30.68 (22.88)	14.14 (10.54)	30.63 (22.84)
BSCD2 G/KW HR (G/HP HR)	1106.97 (825.47)	731.58 (545.54)	980.79 (731.37)	1117.70 (833.47)
BSNOX G/KW HR (G/HP HR)	14.32 (10.68)	11.74 (8.75)	10.66 (7.95)	15.07 (11.24)
BSFC KG/KW HR (LB/HP HR)	.373 (.613)	.254 (.417)	.317 (.522)	.376 (.619)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	9.34 (12.53)
BSHC G/KW HR (G/HP HR)	5.44 (4.06) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	21.44 (15.99)
BSCD2 G/KW HR (G/HP HR)	967. (721.)
BSNOX G/KW HR (G/HP HR)	11.86 (8.84) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.320 (.525)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	16.568
	G/KWHR(G/HPHR)	1.77 (1.32)
	G/KG FUEL (G/LB FUEL)	5.55 (2.52)
	FILTER EFF.	93.4

TABLE A-15. HIGH ALTITUDE STEADY-STATE IDLE MODE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. HA 2 RUN1
DATE 5/26/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 737.11 MM HG(29.02 IN HG)
DRY BULB TEMP. (ENG.) 31.1 DEG C(88.0 DEG F)

RELATIVE HUMIDITY, ENGINE-47. PCT, CVS-37. PCT ENG. DEW PT. 65.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 13.7 GM/KG(95.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0566

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	901.8
TOT. BLOWER RATE SCMH (SCFM)	57.47 (2029.2)
TOT. 90MM RATE SCMH (SCFM)	.02 (.80)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	864.1 (30511.)

HC SAMPLE METER/RANGE/PPM	26.0/41/ 25.95
HC BCKGRD METER/RANGE/PPM	4.4/41/ 4.40
CO SAMPLE METER/RANGE/PPM	27.2/12/ 26.80
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	24.8/14/ .0974
CO2 BCKGRD METER/RANGE/PCT	10.7/14/ .0350
NOX SAMPLE METER/RANGE/PPM	4.5/43/ 11.30
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .13

DILUTION FACTOR	130.51
HC CONCENTRATION PPM	21.59
CO CONCENTRATION PPM	26.42
CO2 CONCENTRATION PCT	.0627
NOX CONCENTRATION PPM	10.91

HC MASS GRAMS	10.755
CO MASS GRAMS	26.580
CO2 MASS GRAMS	991.44
NOX MASS GRAMS	19.051
FUEL KG (LB)	.335 (.74)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS
BOTH FILTERS USED FOR PARTICULATE
90MM PARTICULATE RATES GRAMS/TEST

2.344

6/KG FUEL (6/LB FUEL) 6.99 (3.17)
FILTER EFF. 70.2

TABLE A-16. HIGH ALTITUDE STEADY-STATE INTERMEDIATE EMISSION
RESULTS FOR THE CATERPILLAR 3208 - RUN 2

ENGINE NO.
ENGINE MODEL 0 CATERPIL 3208A
ENGINE 10.4 L(636. CID) V-8
CVS NO. 27

TEST NO. HA- 2 RUN1
DATE 5/26/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 736.85 MM HG(29.01 IN HG)
DRY PULB TEMP. (ENG.) 30.6 DEG C(87.0 DEG F)

RELATIVE HUMIDITY, ENGINE-46. PCT, CVS-34. PCT ENG. DEW PT. 64.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 13.2 GM/KG(92.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0471

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.5
TOT. BLOWER RATE SCMH (SCFM)	56.88 (2008.5)
TOT. 90MM RATE SCMH (SCFM)	.02 (.79)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	854.0 (30156.)

HC SAMPLE METER/RANGE/PPM	45.6/41/ 45.57
HC BCKGRD METER/RANGE/PPM	8.0/41/ 8.00
CO SAMPLE METER/RANGE/PPM	33.2/12/ 32.66
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	82.9/14/ .7133
CO2 BCKGRD METER/RANGE/PCT	10.9/14/ .0357
NOX SAMPLE METER/RANGE/PPM	46.6/43/116.39
NOX BCKGRD METER/RANGE/PPM	.1/ 3/ .25

DILUTION FACTOR	18.58
HC CONCENTRATION PPM	38.00
CO CONCENTRATION PPM	31.85
CO2 CONCENTRATION PCT	.6795
NOX CONCENTRATION PPM	112.97

HC MASS GRAMS	18.713
CO MASS GRAMS	31.668
CO2 MASS GRAMS	10616.37
NOX MASS GRAMS	193.204
FUEL KG (LB)	3.368 (7.43)
KW HR (HP HR)	13.04 (17.49)

BSHC G/KW HR (G/HP HR)	1.43 (1.07)
BSCD G/KW HR (G/HP HR)	2.43 (1.81)
BSCD2 G/KW HR (G/HP HR)	814.00 (607.00)
BSNOX G/KW HR (G/HP HR)	14.81 (11.05)
BSFC KG/KW HR (LB/HP HR)	.258 (.425)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	13.04 (17.49)
BSHC G/KW HR (G/HP HR)	1.43 (1.07) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	2.43 (1.81)
BSCD2 G/KW HR (G/HP HR)	814. (607.)
BSNOX G/KW HR (G/HP HR)	14.81 (11.05) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.258 (.425)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	8.943
	G/KWHR(G/HPHR)	.69 (.51)
	G/KG FUEL (G/LB FUEL)	2.66 (1.20)
	FILTER EFF.	87.2

APPENDIX B

**TRANSIENT AND STEADY-STATE ALDEHYDE
RESULTS FROM CATERPILLAR 3208**

**TABLE B-1. LOW ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE
CATERPILLAR 3208 - RUN 1**

Aldehyde	Cold-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	1,890	147
Acetaldehyde	872	68
Acrolein	474	37
Acetone	156	12
Propionaldehyde	222	17
Crotonaldehyde	108	8
Isobutyraldehyde + MEK	325	25
Benzaldehyde	147	11
Hexanaldehyde	<u>131</u>	<u>10</u>
Total Aldehydes	4,330	335

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	1,260	104
Acetaldehyde	488	43
Acrolein	307	24
Acetone	61	5
Propionaldehyde	113	9
Crotonaldehyde	61	5
Isobutyraldehyde + MEK	209	16
Benzaldehyde	74	6
Hexanaldehyde	<u>49</u>	<u>4</u>
Total Aldehydes	2,620	216

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	533	2,130
Acetaldehyde	216	865
Acrolein	157	630
Acetone	21	85
Propionaldehyde	54	216
Crotonaldehyde	22	90
Isobutyraldehyde + MEK	95	380
Benzaldehyde	27	109
Hexanaldehyde	<u>19</u>	<u>74</u>
Total Aldehydes	1,140	4,580

Aldehyde	1680 RPM at 50% Load	
	mg/test	mg/hp-hr
Formaldehyde	650	39
Acetaldehyde	271	16
Acrolein	116	7
Acetone	25	2
Propionaldehyde	73	4
Crotonaldehyde	34	2
Isobutyraldehyde + MEK	123	7
Benzaldehyde	43	3
Hexanaldehyde	<u>35</u>	<u>2</u>
Total Aldehydes	1,370	82

^aValues are generally considered usable to only two significant figures.

**TABLE B-2. LOW ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE
CATERPILLAR 3208 - RUN 2**

Aldehyde	Cold-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	1,990	155
Acetaldehyde	826	64
Acrolein	179	14
Acetone	580	45
Propionaldehyde	195	15
Crotonaldehyde	117	9
Isobutyraldehyde + MEK	402	31
Benzaldehyde	232	18
Hexanaldehyde	43	4
Total Aldehydes	4,560	355

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	1,330	104
Acetaldehyde	514	40
Acrolein	119	9
Acetone	338	26
Propionaldehyde	122	10
Crotonaldehyde	66	5
Isobutyraldehyde + MEK	255	20
Benzaldehyde	172	13
Hexanaldehyde	44	4
Total Aldehydes	2,960	231

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	670	2,680
Acetaldehyde	247	987
Acrolein	48	192
Acetone	144	575
Propionaldehyde	52	208
Crotonaldehyde	24	97
Isobutyraldehyde + MEK	135	538
Benzaldehyde	52	207
Hexanaldehyde	34	135
Total Aldehydes	1,410	5,620

Aldehyde	1680 RPM at 50% Load	
	mg/test	mg/hp-hr
Formaldehyde	626	37
Acetaldehyde	226	13
Acrolein	37	2
Acetone	136	8
Propionaldehyde	47	3
Crotonaldehyde	30	2
Isobutyraldehyde + MEK	126	8
Benzaldehyde	45	3
Hexanaldehyde	37	2
Total Aldehydes	1,310	78

^aValues are generally considered usable to only two significant figures.

**TABLE B-3. HIGH ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE
CATERPILLAR 3208 - RUN 1**

Aldehyde	Cold-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	6,830	571
Acetaldehyde	2,750	230
Acrolein	1,730	145
Acetone	828	69
Propionaldehyde	986	82
Crotonaldehyde	498	42
Isobutyraldehyde + MEK	1,330	111
Benzaldehyde	866	72
Hexanaldehyde	<u>1,160</u>	<u>97</u>
Total Aldehydes	17,000	1,420

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	2,690	213
Acetaldehyde	1,040	82
Acrolein	671	53
Acetone	246	19
Propionaldehyde	322	25
Crotonaldehyde	191	15
Isobutyraldehyde + MEK	525	42
Benzaldehyde	339	27
Hexanaldehyde	<u>201</u>	<u>16</u>
Total Aldehydes	6,230	492

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	652	2,6107
Acetaldehyde	264	1,060
Acrolein	188	751
Acetone	52	208
Propionaldehyde	71	285
Crotonaldehyde	41	163
Isobutyraldehyde + MEK	7	260
Benzaldehyde	54	217
Hexanaldehyde	<u>31</u>	<u>123</u>
Total Aldehydes	1,360	5,680

Aldehyde	1680 RPM at 50% Load	
	mg/test	mg/hp-hr
Formaldehyde	876	53
Acetaldehyde	351	21
Acrolein	233	14
Acetone	66	4
Propionaldehyde	108	7
Crotonaldehyde	50	3
Isobutyraldehyde + MEK	157	10
Benzaldehyde	60	3
Hexanaldehyde	<u>49</u>	<u>3</u>
Total Aldehydes	1,950	119

^aValues are generally considered usable to only two significant figures.

**TABLE B-4. HIGH ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE
CATERPILLAR 3208 - RUN 2**

<u>Aldehyde</u>	<u>Cold-Start Emissions</u>	
	<u>mg/test</u>	<u>mg/hp-hr</u>
Formaldehyde		
Acetaldehyde		
Acrolein		
Acetone		
Propionaldehyde		
Crotonaldehyde		Aldehyde Sampling Failure
Isobutyraldehyde + MEK		
Benzaldehyde		
Hexanaldehyde		
Total Aldehydes		

<u>Aldehyde</u>	<u>Hot-Start Emissions</u>	
	<u>mg/test</u>	<u>mg/hp-hr</u>
Formaldehyde		
Acetaldehyde		
Acrolein		
Acetone		
Propionaldehyde		
Crotonaldehyde		Aldehyde Sampling Failure
Isobutyraldehyde + MEK		
Benzaldehyde		
Hexanaldehyde		
Total Aldehydes		

<u>Aldehyde</u>	<u>Idle Emissions</u>	
	<u>mg/test</u>	<u>mg/hr</u>
Formaldehyde		
Acetaldehyde		
Acrolein		
Acetone		
Propionaldehyde		
Crotonaldehyde		Aldehyde Sampling Failure
Isobutyraldehyde + MEK		
Benzaldehyde		
Hexanaldehyde		
Total Aldehydes		

<u>Aldehyde</u>	<u>1680 RPM at 50% Load</u>	
	<u>mg/test</u>	<u>mg/hp-hr</u>
Formaldehyde		
Acetaldehyde		
Acrolein		
Acetone		
Propionaldehyde		
Crotonaldehyde		Aldehyde Sampling Failure
Isobutyraldehyde + MEK		
Benzaldehyde		
Hexanaldehyde		
Total Aldehydes		

^aValues are generally considered usable to only two significant figures.

APPENDIX C

**SEGMENT BY SEGMENT TRANSIENT AND STEADY-STATE
REGULATED EMISSION RESULTS FROM CUMMINS NTC-350**

**TABLE C-1. LOW ALTITUDE COLD-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. LA-1 RUN1
DATE 6/ 9/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 737.62 MM HG(29.04 IN HG)
DRY BULB TEMP. (ENG.) 27.8 DEG C(82.0 DEG F)

RELATIVE HUMIDITY , ENGINE-41. PCT , CVS-51. PCT ENG. DEW PT. 56.3 DEG F
ABSOLUTE HUMIDITY (ENG.) 10.0 GM/KG(69.7 GRAINS/LB) NOX HUMIDITY C.F. .9865

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.2	300.2	304.7	306.1
TOT. BLOWER RATE SCFM (SCFM)	53.14 (1876.3)	52.99 (1871.1)	52.73 (1861.9)	52.66 (1859.5)
TOT. 30MM RATE SCFM (SCFM)	.03 (.91)	.03 (.91)	.03 (.91)	.03 (.91)
TOT. 20X20 RATE SCFM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	262.5 (3267.)	265.3 (9366.)	267.9 (9460.)	268.8 (9491.)
HC SAMPLE METER/RANGE/PPM	95.7/43/ 382.69	65.1/43/ 260.56	21.6/43/ 86.20	24.7/43/ 98.79
HC BCKGRD METER/RANGE/PPM	1.2/43/ 4.80	1.2/43/ 4.80	1.2/43/ 4.80	1.2/43/ 4.80
CO SAMPLE METER/RANGE/PPM	41.7/13/ 96.64	43.4/13/100.74	81.7/12/ 81.72	84.0/12/ 84.09
CO BCKGRD METER/RANGE/PPM	.0/13/ .00	.8/13/ 1.83	1.6/12/ 1.62	1.6/12/ 1.62
CO2 SAMPLE METER/RANGE/PCT	75.4/14/ .5806	84.5/14/ .7452	91.8/ 1/1.7058	68.6/14/ .4801
CO2 BCKGRD METER/RANGE/PCT	16.6/14/ .0586	17.9/14/ .0643	4.2/ 1/ .0743	15.6/14/ .0544
NOX SAMPLE METER/RANGE/PPM	8.3/43/ 20.78	12.1/43/ 30.33	39.0/43/ 97.57	9.2/43/ 23.05
NOX BCKGRD METER/RANGE/PPM	1.9/ 1/ .50	.7/ 2/ .71	1.9/ 2/ 1.91	2.9/ 1/ .76
DILUTION FACTOR	21.33	17.16	7.78	26.90
HC CONCENTRATION PPM	378.12	256.04	82.02	94.17
CO CONCENTRATION PPM	93.95	95.92	76.29	80.38
CO2 CONCENTRATION PCT	.5248	.6847	1.6411	.4277
NOX CONCENTRATION PPM	19.79	28.88	92.50	21.77
HC MASS GRAMS	57.222	39.160	12.670	14.595
CO MASS GRAMS	28.707	29.621	23.794	25.152
CO2 MASS GRAMS	2519.55	3322.56	8043.38	2103.33
NOX MASS GRAMS	9.800	14.453	46.754	11.039
FUEL KG (LB)	.863 (1.90)	1.097 (2.42)	2.550 (5.62)	.687 (1.52)
KW HR (HP HR)	2.18 (2.93)	3.32 (4.45)	9.78 (13.12)	2.18 (2.93)
BSHC G/KW HR (G/HP HR)	26.19 (19.53)	11.80 (8.80)	1.30 (.97)	6.68 (4.98)
BSCO G/KW HR (G/HP HR)	13.14 (9.80)	8.93 (6.66)	2.43 (1.81)	11.51 (8.58)
BSCO2 G/KW HR (G/HP HR)	1153.16 (859.91)	1001.26 (746.64)	822.13 (613.06)	962.67 (717.86)
BSNOX G/KW HR (G/HP HR)	4.49 (3.34)	4.36 (3.25)	4.78 (3.56)	5.05 (3.77)
BSFC KG/KW HR (LB/HP HR)	.395 (.649)	.331 (.544)	.261 (.429)	.315 (.517)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.47 (23.43)	PARTICULATE RESULTS, TOTAL FOR 4 BAGS	
BSHC G/KW HR (G/HP HR)	7.08 (5.28) (CONTINUOUS)	***BOTH FILTERS USED FOR PARTICULATE***	
BSCO G/KW HR (G/HP HR)	6.14 (4.58)	90MM PARTICULATE RATES	GRAMS/TEST
BSCO2 G/KW HR (G/HP HR)	915. (682.)		31.077
BSNOX G/KW HR (G/HP HR)	4.70 (3.50) (CONTINUOUS)		G/KWHR(G/HPHR)
BSFC KG/KW HR (LB/HP HR)	.297 (.489)		1.78 (1.33)
			G/KG FUEL (G/LB FUEL)
			5.98 (2.71)
			FILTER EFF.
			92.2

C-2

**TABLE C-2. LOW ALTITUDE HOT-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) 1-6
CVS NO. 27

TEST NO. LA-1 RUN1
DATE 6/ 9/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 737.36 MM HG(29.03 IN HG)
DRY BULB TEMP. (ENG.) 30.6 DEG C(87.0 DEG F)

RELATIVE HUMIDITY , ENGINE-45. PCT , CVS-47. PCT ENG. DEW PT. 63.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 12.7 GM/KG(89.0 GRAINS/LB) NOX HUMIDITY C.F. 1.0377

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	297.1	300.2	304.8	305.9
TOT. BLOWER RATE SCMM (SCFM)	53.16 (1877.0)	52.92 (1868.6)	52.73 (1861.8)	52.80 (1864.5)
TOT. 90MM RATE SCMM (SCFM)	.03 (1.16)	.03 (1.16)	.03 (1.16)	.03 (1.16)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	353.4 (9300.)	354.9 (9355.)	358.0 (9464.)	359.4 (9512.)
HC SAMPLE METER/RANGE/PPM	54.7/42/ 109.28	44.9/42/ 89.64	32.1/42/ 64.21	39.4/42/ 78.75
HC BCKGRD METER/RANGE/PPM	1.9/42/ 3.80	1.9/42/ 3.80	1.9/42/ 3.80	1.9/42/ 3.80
CO SAMPLE METER/RANGE/PPM	92.1/12/ 92.36	93.9/12/ 94.18	75.6/12/ 75.43	77.5/12/ 77.39
CO BCKGRD METER/RANGE/PPM	1.5/12/ 1.52	1.4/12/ 1.42	.8/12/ .81	.9/12/ .91
CO2 SAMPLE METER/RANGE/PCT	70.0/14/ .4995	83.6/14/ .7271	89.9/ 1/1.6689	67.8/14/ .4693
CO2 BCKGRD METER/RANGE/PCT	16.6/14/ .0586	21.1/14/ .0790	5.0/ 1/ .0885	16.9/14/ .0599
NOX SAMPLE METER/RANGE/PPM	8.6/43/ 21.44	13.2/43/ 32.97	39.1/43/ 97.66	9.2/43/ 23.06
NOX BCKGRD METER/RANGE/PPM	1.8/ 1/ .48	.7/ 2/ .71	1.0/ 2/ 1.01	1.2/ 1/ .32
DILUTION FACTOR	25.80	17.98	7.96	27.65
HC CONCENTRATION PPM	105.63	86.06	60.89	75.09
CO CONCENTRATION PPM	88.62	90.10	71.15	74.63
CO2 CONCENTRATION PCT	.4431	.6525	1.5915	.4115
NOX CONCENTRATION PPM	20.46	31.42	93.31	22.19
HC MASS GRAMS	16.041	13.147	9.410	11.664
CO MASS GRAMS	27.173	27.791	22.199	23.405
CO2 MASS GRAMS	2135.17	3162.55	7803.37	2028.10
NOX MASS GRAMS	10.693	16.522	49.632	11.865
FUEL KG (LB)	.700 (1.54)	1.020 (2.25)	2.471 (5.45)	.660 (1.46)
KW HR (HP HR)	2.17 (2.91)	3.35 (4.49)	9.78 (13.12)	2.18 (2.93)
BSHC G/KW HR (G/HP HR)	7.39 (5.51)	3.93 (2.93)	.96 (.72)	5.34 (3.98)
BSCO G/KW HR (G/HP HR)	12.52 (9.34)	8.30 (6.19)	2.27 (1.69)	10.71 (7.99)
BSO2 G/KW HR (G/HP HR)	983.96 (733.74)	944.56 (704.35)	797.60 (594.77)	928.23 (692.18)
BSNOX G/KW HR (G/HP HR)	4.93 (3.67)	4.93 (3.68)	5.07 (3.78)	5.43 (4.05)
BSFC KG/KW HR (LB/HP HR)	.323 (.530)	.305 (.501)	.253 (.415)	.302 (.497)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.49 (23.45)
BSHC G/KW HR (G/HP HR)	2.87 (2.14) (CONTINUOUS)
BSCO G/KW HR (G/HP HR)	5.75 (4.29)
BSO2 G/KW HR (G/HP HR)	865. (645.)
BSNOX G/KW HR (G/HP HR)	5.07 (3.78) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.277 (.456)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	19.839
	G/KWHR(G/HPHR)	1.13 (.85)
	G/KG FUEL (G/LB FUEL)	4.09 (1.85)
	FILTER EFF.	93.0

C-3

TABLE C-3. LOW ALTITUDE STEADY-STATE IDLE MODE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. LA-1-55 RUN1
DATE 6/ 8/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 735.08 MM HG(28.94 IN HG)
DRY BULB TEMP. (ENG.) 42.2 DEG C(*** DEG F)

RELATIVE HUMIDITY , ENGINE-14. PCT , CVS-26. PCT ENG. DEW PT. 48.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 7.3 GM/KG(51.3 GRAINS/LB) NOX HUMIDITY C.F. .9420

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.1
TOT. BLOWER RATE SCMM (SCFM)	52.95 (1869.6)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.43)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	734.9 (28069.)
HC SAMPLE METER/RANGE/PPM	85.1/42/ 170.11
HC BCKGRD METER/RANGE/PPM	3.5/42/ 7.00
CO SAMPLE METER/RANGE/PPM	44.4/12/ 43.70
CO BCKGRD METER/RANGE/PPM	.1/12/ .10
CO2 SAMPLE METER/RANGE/PCT	78.5/12/ .1752
CO2 BCKGRD METER/RANGE/PCT	34.4/12/ .0582
NOX SAMPLE METER/RANGE/PPM	2.2/43/ 5.52
NOX BCKGRD METER/RANGE/PPM	.8/ 1/ .21
DILUTION FACTOR	68.19
HC CONCENTRATION PPM	163.22
CO CONCENTRATION PPM	43.09
CO2 CONCENTRATION PCT	.1178
NOX CONCENTRATION PPM	5.21
HC MASS GRAMS	74.814
CO MASS GRAMS	39.875
CO2 MASS GRAMS	1713.57
NOX MASS GRAMS	7.460
FUEL KG (LB)	.633 (1.39)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS
BOTH FILTERS USED FOR PARTICULATE
90MM PARTICULATE RATES GRAMS/TEST

11.075

G/KG FUEL (G/LB FUEL) 17.51 (7.94)
FILTER EFF. 83.6

**TABLE C-4. LOW ALTITUDE STEADY-STATE INTERMEDIATE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1**

ENGINE NO.	TEST NO. LA-1-55	RUN1
ENGINE MODEL 34 CUMMINS NTC 350	DATE 6/ 8/89	
ENGINE 14.0 L(855. CID) 1-6	TIME	DIESEL EM-834-F
CVS NO. 27	DYNO NO. 4	BAG CART NO. 2

BAROMETER 734.82 MM HG(28.93 IN HG)	RELATIVE HUMIDITY , ENGINE-15. PCT , CVS-25. PCT	ENG. DEW PT. 50.0 DEG F
DRY BULB TEMP. (ENG.) 42.2 DEG C(100 DEG F)	ABSOLUTE HUMIDITY (ENG.) 7.9 GM/KG(55.4 GRAINS/LB)	NOX HUMIDITY C.F. .9514

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	899.8
TOT. BLOWER RATE SCMM (SCFM)	52.52 (1854.6)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.32)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	788.2 (27833.)

HC SAMPLE METER/RANGE/PPM	17.8/42/ 35.57
HC BCKGRD METER/RANGE/PPM	4.3/42/ 8.59
CO SAMPLE METER/RANGE/PPM	36.4/12/ 86.55
CO BCKGRD METER/RANGE/PPM	.2/12/ .20
CO2 SAMPLE METER/RANGE/PCT	74.1/ 1/1.3668
CO2 BCKGRD METER/RANGE/PCT	3.2/ 1/ .0565
NOX SAMPLE METER/RANGE/PPM	36.7/43/ 91.76
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ .60

DILUTION FACTOR	3.72
HC CONCENTRATION PPM	27.86
CO CONCENTRATION PPM	83.39
CO2 CONCENTRATION PCT	1.3161
NOX CONCENTRATION PPM	88.50

HC MASS GRAMS	12.662
CO MASS GRAMS	76.520
CO2 MASS GRAMS	18978.75
NOX MASS GRAMS	126.926
FUEL KG (LB)	6.010 (13.25)
KW HR (HP HR)	24.54 (32.91)

BSHC G/KW HR (G/HP HR)	.52 (.38)
ESCO G/KW HR (G/HP HR)	3.12 (2.33)
BSC02 G/KW HR (G/HP HR)	773.35 (576.69)
BSNOX G/KW HR (G/HP HR)	5.17 (3.86)
BSFC KG/KW HR (LB/HP HR)	.245 (.403)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	24.54 (32.91)
BSHC G/KW HR (G/HP HR)	.52 (.38) (CONTINUOUS)
ESCO G/KW HR (G/HP HR)	3.12 (2.33)
BSC02 G/KW HR (G/HP HR)	773. (577.)
BSNOX G/KW HR (G/HP HR)	5.17 (3.86) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.245 (.403)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	20.718
	G/KWHR(G/HPHR)	.84 (.63)
	G/KG FUEL (G/LB FUEL)	3.45 (1.56)
	FILTER EFF.	98.5

**TABLE C-5. LOW ALTITUDE COLD-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2**

ENGINE NO.	TEST NO. LA-2	RUN1		
ENGINE MODEL 34 CUMMINS NTC 350	DATE 6/12/89			
ENGINE 14.0 L (855. CID) I-6	TIME	DIESEL EM-834-F		
CVS NO. 27	DYNO NO. 4	BAG CART NO. 2		
BAROMETER 738.38 MM HG (29.07 IN HG)		RELATIVE HUMIDITY , ENGINE-57. PCT , CVS-54. PCT ENG. DEW PT. 68.9 DEG F		
DRY BULB TEMP. (ENG.) 30.0 DEG C (86.0 DEG F)		ABSOLUTE HUMIDITY (ENG.) 15.7 GM/KG (109.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0988		
BAG RESULTS				
BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.8	300.2	305.4	305.9
TOT. BLOWER RATE SCMH (SCFM)	52.56 (1855.7)	52.28 (1846.2)	51.46 (1817.0)	51.78 (1828.5)
TOT. 90MM RATE SCMH (SCFM)	.03 (1.18)	.03 (1.18)	.03 (1.18)	.03 (1.18)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES (SCF)	360.1 (3186.)	261.8 (9243.)	262.1 (9255.)	264.2 (9328.)
HC SAMPLE METER/RANGE/PPM	62.9/44/ 501.42	37.8/44/ 302.22	9.9/44/ 78.41	10.6/44/ 84.31
HC BCKGRD METER/RANGE/PPM	.3/44/ 7.05	.3/44/ 7.05	.3/44/ 7.05	.3/44/ 7.05
CO SAMPLE METER/RANGE/PPM	41.7/13/ 96.64	50.1/13/117.07	39.7/13/ 91.85	38.4/13/ 88.74
CO BCKGRD METER/RANGE/PPM	.4/13/ .91	.6/13/ 1.37	.3/13/ .69	.4/13/ .91
CO2 SAMPLE METER/RANGE/PCT	75.4/14/ .5806	83.7/14/ .7291	93.1/ 1/1.7312	68.0/14/ .4720
CO2 BCKGRD METER/RANGE/PCT	11.8/14/ .0391	12.3/14/ .0411	2.4/ 1/ .0423	11.7/14/ .0388
NOX SAMPLE METER/RANGE/PPM	8.2/43/ 20.37	11.9/43/ 29.73	37.4/43/ 93.46	8.9/43/ 22.36
NOX BCKGRD METER/RANGE/PPM	1.6/ 1/ .42	.3/ 2/ .30	1.0/ 2/ 1.01	1.5/ 1/ .40
DILUTION FACTOR	20.93	17.39	7.67	27.40
HC CONCENTRATION PPM	494.71	295.58	72.28	77.51
CO CONCENTRATION PPM	93.01	112.09	86.58	85.51
CO2 CONCENTRATION PCT	.5434	.6904	1.6944	.4346
NOX CONCENTRATION PPM	13.36	28.52	98.80	21.33
HC MASS GRAMS	74.206	44.613	10.923	11.807
CO MASS GRAMS	28.166	34.159	26.418	26.299
CO2 MASS GRAMS	2585.82	3306.08	8124.08	2100.56
NOX MASS GRAMS	10.584	15.687	48.903	11.840
FUEL KG (LB)	.900 (1.98)	1.100 (2.42)	2.575 (5.68)	.684 (1.51)
KW HR (HP HR)	2.18 (2.92)	3.35 (4.49)	9.90 (13.28)	2.24 (3.01)
BSHC G/KW HR (G/HP HR)	34.08 (25.41)	13.32 (9.94)	1.10 (.82)	5.26 (3.92)
BSCO G/KW HR (G/HP HR)	12.94 (9.65)	10.20 (7.61)	2.67 (1.99)	11.72 (8.74)
BSCD2 G/KW HR (G/HP HR)	1187.55 (885.56)	987.42 (736.32)	820.37 (611.75)	935.84 (697.86)
BSNOX G/KW HR (G/HP HR)	4.86 (3.62)	4.69 (3.49)	4.94 (3.68)	5.27 (3.93)
BSFC KG/KW HR (LB/HP HR)	.413 (.680)	.328 (.540)	.260 (.427)	.305 (.501)
TOTAL TEST RESULTS 4 BAGS		PARTICULATE RESULTS, TOTAL FOR 4 BAGS		
		BOTH FILTERS USED FOR PARTICULATE		
TOTAL KW HR (HP HR)	17.67 (23.70)	90MM PARTICULATE RATES	GRAMS/TEST	32.812
BSHC G/KW HR (G/HP HR)	8.01 (5.97) (CONTINUOUS)		G/KWHR (G/HPHR)	1.86 (1.38)
BSCO G/KW HR (G/HP HR)	6.51 (4.85)		G/KG FUEL (G/LB FUEL)	5.24 (2.83)
BSCD2 G/KW HR (G/HP HR)	912. (680.)		FILTER EFF.	92.0
BSNOX G/KW HR (G/HP HR)	4.92 (3.67) (CONTINUOUS)	C-6		
BSFC KG/KW HR (LB/HP HR)	.298 (.489)			

**TABLE C-6. LOW ALTITUDE HOT-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. LA-2 RUN1
DATE 6/12/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 738.12 MM HG(29.06 IN HG)
DRY BULB TEMP. (ENG.) 35.0 DEG C(95.0 DEG F)

RELATIVE HUMIDITY, ENGINE-44. PCT, CVS-48. PCT ENG. DEW PT. 69.5 DEG F
ABSOLUTE HUMIDITY (ENG.) 16.0 GM/KG(111.9 GRAINS/LB) NOX HUMIDITY C.F. 1.1063

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.4	300.4	304.9	305.8
TOT. BLOWER RATE SCFM (SCFM)	52.45 (1851.9)	52.33 (1847.8)	51.97 (1835.1)	51.90 (1832.5)
TOT. 90MM RATE SCFM (SCFM)	.03 (1.12)	.03 (1.12)	.03 (1.12)	.03 (1.12)
TOT. 20X20 RATE SCFM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	259.2 (9154.)	262.2 (9257.)	264.3 (9331.)	264.7 (9345.)
HC SAMPLE METER/RANGE/PPM	56.9/42/ 113.71	45.2/42/ 90.35	33.0/42/ 65.89	39.6/42/ 79.06
HC BCKGRD METER/RANGE/PPM	3.4/42/ 6.80	3.4/42/ 6.80	3.4/42/ 6.80	3.4/42/ 6.80
CO SAMPLE METER/RANGE/PPM	40.6/13/ 94.00	40.5/13/ 93.76	78.1/12/ 78.01	78.0/12/ 77.90
CO BCKGRD METER/RANGE/PPM	.1/13/ .23	.1/13/ .23	.2/12/ .20	.2/12/ .20
CO2 SAMPLE METER/RANGE/PCT	68.4/14/ .4774	81.5/14/ .6865	89.8/ 1/1.6670	65.9/14/ .4444
CO2 BCKGRD METER/RANGE/PCT	11.3/14/ .0372	11.6/14/ .0384	2.4/ 1/ .0423	11.4/14/ .0376
NOX SAMPLE METER/RANGE/PPM	8.3/43/ 20.77	13.0/43/ 32.47	38.6/43/ 96.45	8.9/43/ 22.25
NOX BCKGRD METER/RANGE/PPM	1.6/ 1/ .42	.6/ 2/ .60	.7/ 2/ .71	1.6/ 1/ .42
DILUTION FACTOR	26.91	19.02	7.97	29.13
HC CONCENTRATION PPM	107.17	83.91	59.95	72.50
CO CONCENTRATION PPM	91.46	90.85	74.11	75.83
CO2 CONCENTRATION PCT	.4415	.6501	1.6299	.4081
NOX CONCENTRATION PPM	19.74	30.87	31.89	21.18
HC MASS GRAMS	16.020	12.684	9.134	11.064
CO MASS GRAMS	27.602	27.726	22.801	23.364
CO2 MASS GRAMS	2093.96	3118.05	7879.85	1975.88
NOX MASS GRAMS	10.826	17.119	51.374	11.859
FUEL KG (LB)	.687 (1.51)	1.005 (2.22)	2.495 (5.50)	.643 (1.42)
KW HR (HP HR)	2.15 (2.88)	3.33 (4.47)	9.72 (13.03)	2.16 (2.90)
BSHC G/KW HR (G/HP HR)	7.46 (5.56)	3.81 (2.84)	.94 (.70)	5.12 (3.82)
BSCD G/KW HR (G/HP HR)	12.85 (9.58)	8.32 (6.20)	2.35 (1.75)	10.80 (8.06)
ESCD2 G/KW HR (G/HP HR)	975.02 (727.07)	935.43 (697.55)	810.98 (604.75)	913.69 (681.34)
BSNOX G/KW HR (G/HP HR)	5.04 (3.76)	5.14 (3.83)	5.29 (3.94)	5.48 (4.09)
BSFC KG/KW HR (LB/HP HR)	.320 (.526)	.302 (.496)	.257 (.422)	.297 (.489)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.36 (23.28)
BSHC G/KW HR (G/HP HR)	2.82 (2.10) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	5.85 (4.36)
ESCD2 G/KW HR (G/HP HR)	868. (647.)
BSNOX G/KW HR (G/HP HR)	5.25 (3.92) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.278 (.457)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	19.283
	G/KWHR(G/HPHR)	1.11 (.83)
	G/KG FUEL (G/LB FUEL)	3.99 (1.81)
	FILTER EFF.	95.8

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TABLE C-7. LOW ALTITUDE STEADY-STATE IDLE MODE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2

ENGINE NO.	TEST NO. LA-2-SS	RUN1
ENGINE MODEL 84 CUMMINS NTC 350	DATE 6/ 9/89	
ENGINE 14.0 L(855. CID) I-6	TIME	DIESEL EM-834-F
CVS NO. 27	DYNO NO. 4	BAG CART NO. 2
BAROMETER 737.36 MM HG(29.03 IN HG)		
RELATIVE HUMIDITY , ENGINE-31. PCT , CVS-51. PCT ENG. DEW PT. 54.0 DEG F		
DRY BULB TEMP. (ENG.) 31.1 DEG C(88.0 DEG F)		
ABSOLUTE HUMIDITY (ENG.) 9.2 GM/KG(64.1 GRAINS/LB) NOX HUMIDITY C.F. .9724		
BAG RESULTS		
BAG NUMBER	1	
TIME SECONDS	900.3	
TOT. BLOWER RATE SCFM (SCFM)	53.23 (1879.5)	
TOT. 30MM RATE SCFM (SCFM)	.04 (1.44)	
TOT. 20X20 RATE SCFM (SCFM)	.00 (.0)	
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)	
TOTAL FLOW STD. CU. METRES(SCF)	799.3 (28223.)	
HC SAMPLE METER/RANGE/PPM	82.5/42/ 164.83	
HC BCKGRD METER/RANGE/PPM	3.2/42/ 6.40	
CO SAMPLE METER/RANGE/PPM	46.5/12/ 45.79	
CO BCKGRD METER/RANGE/PPM	1.1/12/ 1.12	
CO2 SAMPLE METER/RANGE/PCT	64.6/12/ .1323	
CO2 BCKGRD METER/RANGE/PCT	26.7/12/ .0430	
NOX SAMPLE METER/RANGE/PPM	1.8/43/ 4.44	
NOX BCKGRD METER/RANGE/PPM	1.0/ 1/ .26	
DILUTION FACTOR	87.41	
HC CONCENTRATION PPM	158.51	
CO CONCENTRATION PPM	43.84	
CO2 CONCENTRATION PCT	.0899	
NOX CONCENTRATION PPM	4.07	
HC MASS GRAMS	73.055	
CO MASS GRAMS	40.790	
CO2 MASS GRAMS	1314.06	
NOX MASS GRAMS	6.052	
FUEL KG (LB)	.506 (1.12)	

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	13.996
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6/KG FUEL (6/LB FUEL)	27.67 (12.55)
FILTER EFF.	81.2

TABLE C-8. LOW ALTITUDE STEADY-STATE INTERMEDIATE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2

ENGINE NO.	TEST NO. LA-2-SS	RUN1
ENGINE MODEL 84 CUMMINS NTC 350	DATE 6/ 9/89	
ENGINE 14.0 L(855. CID) I-6	TIME	DIESEL EM-834-F
CYS NO. 27	DYNO NO. 4	BAG CART NO. 2

BAROMETER 737.36 MM HG (29.03 IN HG)	RELATIVE HUMIDITY , ENGINE-29. PCT , CYS-49. PCT	ENG. DEW PT. 52.0 DEG F
DRY BULB TEMP. (ENG.) 31.1 DEG C (88.0 DEG F)	ABSOLUTE HUMIDITY (ENG.) 8.5 GM/KG (59.5 GRAINS/LB)	NOX HUMIDITY C.F. .9612

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.2
TOT. BLOWER RATE SCMM (SCFM)	52.23 (1844.3)
TOT. 30MM RATE SCMM (SCFM)	.02 (.74)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	783.3 (27681.)

HC SAMPLE METER/RANGE/PPM	15.1/42/ 30.25
HC BCKGRD METER/RANGE/PPM	3.5/42/ 7.00
CO SAMPLE METER/RANGE/PPM	79.2/12/ 79.14
CO BCKGRD METER/RANGE/PPM	1.5/12/ 1.52
CO2 SAMPLE METER/RANGE/PCT	73.4/ 1/1.3536
CO2 BCKGRD METER/RANGE/PCT	3.0/ 1/ .0530
VOX SAMPLE METER/RANGE/PPM	32.2/43/ 80.61
VOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.01

DILUTION FACTOR	3.82
HC CONCENTRATION PPM	23.96
CO CONCENTRATION PPM	74.48
CO2 CONCENTRATION PCT	1.3060
VOX CONCENTRATION PPM	76.85

HC MASS GRAMS	10.832
CO MASS GRAMS	67.975
CO2 MASS GRAMS	18730.59
VOX MASS GRAMS	110.749
FUEL KG (LB)	5.926 (13.06)
HP HR (HP HR)	24.55 (32.92)

BSHC G/KW HR (G/HP HR)	.44 (.33)
BSCD G/KW HR (G/HP HR)	2.77 (2.06)
BSCO2 G/KW HR (G/HP HR)	763.01 (568.97)
BSNOX G/KW HR (G/HP HR)	4.51 (3.36)
BSFC KG/KW HR (LB/HP HR)	.241 (.337)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	24.55 (32.92)
BSHC G/KW HR (G/HP HR)	.44 (.33) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	2.77 (2.06)
BSCO2 G/KW HR (G/HP HR)	763. (569.)
BSNOX G/KW HR (G/HP HR)	4.51 (3.36) (CONTINUOUS)
BSFC G/KW HR (LB/HP HR)	.241 (.337)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	23.227
	G/KWHR(G/HPHR)	.95 (.71)
	G/KG FUEL (G/LB FUEL)	3.92 (1.78)
	FILTER EFF.	97.1

TABLE C-9. HIGH ALTITUDE COLD-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. HA-1 RUN1
DATE 6/13/89
TIME
DYNQ NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 737.62 MM HG(29.04 IN HG)
DRY BULB TEMP. (ENG.) 29.4 DEG C(85.0 DEG F)

RELATIVE HUMIDITY , ENGINE-53. PCT , CVS-54. PCT ENG. DEW PT. 66.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 14.1 GM/KG(99.0 GRAINS/LB) NOX HUMIDITY C.F. 1.0666

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.1	304.0	301.1	305.9
TOT. BLOWER RATE SCMM (SCFM)	51.06 (1802.8)	50.67 (1789.1)	50.00 (1765.7)	49.65 (1753.2)
TOT. 90MM RATE SCMM (SCFM)	.02 (.58)	.02 (.58)	.02 (.58)	.02 (.58)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	252.0 (8899.)	256.8 (9068.)	251.0 (8864.)	253.2 (8942.)
HC SAMPLE METER/RANGE/PPM	91.4/44/ 734.02	66.7/44/ 531.33	16.9/44/ 134.38	47.0/44/ 375.61
HC BCKGRD METER/RANGE/PPM	1.0/44/ 7.84	1.0/44/ 7.84	1.0/44/ 7.84	1.0/44/ 7.84
CO SAMPLE METER/RANGE/PPM	84.2/13/205.47	82.3/13/200.30	68.4/13/163.36	73.2/13/175.94
CO BCKGRD METER/RANGE/PPM	.4/13/ .91	.6/13/ 1.37	.5/13/ 1.14	.4/13/ .91
CO2 SAMPLE METER/RANGE/PCT	76.2/14/ .5936	84.6/14/ .7473	95.3/ 1/1.7743	69.2/14/ .4883
CO2 BCKGRD METER/RANGE/PCT	11.7/14/ .0388	13.0/14/ .0438	2.5/ 1/ .0441	11.7/14/ .0388
NOX SAMPLE METER/RANGE/PPM	8.9/43/ 22.12	10.9/43/ 27.23	35.5/43/ 88.82	8.4/43/ 20.94
NOX BCKGRD METER/RANGE/PPM	1.7/ 1/ .45	.2/ 2/ .20	.7/ 2/ .71	.9/ 1/ .24
DILUTION FACTOR	19.51	16.35	7.43	24.68
HC CONCENTRATION PPM	726.58	523.97	127.59	368.09
CO CONCENTRATION PPM	198.68	192.66	153.96	170.36
CO2 CONCENTRATION PCT	.5568	.7062	1.7361	.4511
NOX CONCENTRATION PPM	21.05	26.21	84.66	20.13
HC MASS GRAMS	105.593	77.585	18.468	53.747
CO MASS GRAMS	58.297	57.596	44.992	50.221
CO2 MASS GRAMS	2567.36	3317.47	7972.51	2089.89
NOX MASS GRAMS	10.824	13.730	43.345	10.396
FUEL KG (LB)	.941 (2.07)	1.148 (2.53)	2.544 (5.61)	.735 (1.62)
KW HR (HP HR)	2.03 (2.72)	3.21 (4.30)	9.71 (13.02)	2.13 (2.85)
BSHC G/KW HR (G/HP HR)	52.06 (38.82)	24.20 (18.04)	1.90 (1.42)	25.29 (18.86)
BSCD G/KW HR (G/HP HR)	28.74 (21.43)	17.96 (13.39)	4.63 (3.46)	23.63 (17.62)
BSCD2 G/KW HR (G/HP HR)	1265.77 (943.88)	1034.60 (771.50)	821.15 (612.33)	983.37 (733.30)
BSNOX G/KW HR (G/HP HR)	5.34 (3.98)	4.28 (3.19)	4.46 (3.33)	4.89 (3.65)
BSFC KG/KW HR (LB/HP HR)	.464 (.762)	.358 (.588)	.262 (.431)	.346 (.568)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.07 (22.89)
BSHC G/KW HR (G/HP HR)	14.96 (11.16) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	12.37 (9.22)
BSCD2 G/KW HR (G/HP HR)	934. (697.)
BSNOX G/KW HR (G/HP HR)	4.59 (3.42) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.314 (.517)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	66.970
	G/KWHR(G/HPHR)	3.92 (2.93)
	G/KG FUEL (G/LB FUEL)	12.48 (5.66)
	FILTER EFF.	95.8

C-10

**TABLE C-10. HIGH ALTITUDE HOT-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. HA-1 RUN1
DATE 6/13/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 737.11 MM HG(29.02 IN HG)
DRY BULB TEMP. (ENG.) 29.4 DEG C(85.0 DEG F)

RELATIVE HUMIDITY, ENGINE-55. PCT, CVS-49. PCT ENG. DEW PT. 67.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 14.7 GM/KG(102.7 GRAINS/LB) NOX HUMIDITY C.F. 1.0775

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.7	300.1	305.1	306.3
TOT. BLOWER RATE SCMH (SCFM)	50.91 (1797.7)	50.63 (1787.6)	50.02 (1766.2)	49.98 (1764.7)
TOT. 30MM RATE SCMH (SCFM)	.02 (.61)	.02 (.61)	.02 (.61)	.02 (.61)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	251.8 (8893.)	253.3 (8944.)	254.4 (8984.)	255.2 (9012.)
HC SAMPLE METER/RANGE/PPM	34.2/43/ 376.81	72.2/43/ 288.66	25.1/43/ 100.25	73.3/43/ 293.35
HC BCKGRD METER/RANGE/PPM	.8/43/ 3.20	.8/43/ 3.20	.8/43/ 3.20	.8/43/ 3.20
CO SAMPLE METER/RANGE/PPM	79.5/13/192.74	79.2/13/191.93	58.4/13/137.74	66.6/13/158.69
CO BCKGRD METER/RANGE/PPM	.0/13/ .00	.1/13/ .23	.0/13/ .00	.0/13/ .00
CO2 SAMPLE METER/RANGE/PCT	68.5/14/ .4787	82.4/14/ .7036	89.9/ 1/1.6689	67.6/14/ .4666
CO2 BCKGRD METER/RANGE/PCT	11.1/14/ .0365	11.3/14/ .0372	3.4/ 1/ .0423	11.1/14/ .0365
NOX SAMPLE METER/RANGE/PPM	7.4/43/ 18.44	11.5/43/ 28.67	35.4/43/ 88.48	8.3/43/ 20.68
NOX BCKGRD METER/RANGE/PPM	.7/ 1/ .19	.0/ 2/ .00	.3/ 2/ .30	.1/ 1/ .03
DILUTION FACTOR	25.04	17.84	7.92	26.20
HC CONCENTRATION PPM	373.74	285.64	97.45	290.27
CO CONCENTRATION PPM	187.90	186.07	131.14	154.75
CO2 CONCENTRATION PCT	.4437	.6685	1.6319	.4315
NOX CONCENTRATION PPM	17.76	27.82	34.83	20.09
HC MASS GRAMS	54.273	41.721	14.297	42.713
CO MASS GRAMS	55.092	54.872	38.843	45.981
CO2 MASS GRAMS	2044.24	3097.66	7596.03	2014.86
NOX MASS GRAMS	9.216	14.523	44.474	10.568
FUEL KG (LB)	.723 (1.59)	1.041 (2.30)	2.419 (5.33)	.698 (1.54)
KW HR (HP HR)	2.10 (2.82)	3.28 (4.40)	9.72 (13.04)	2.21 (2.97)
BSHC G/KW HR (G/HP HR)	25.81 (19.25)	12.72 (9.48)	1.47 (1.10)	19.29 (14.38)
BSCD G/KW HR (G/HP HR)	26.20 (19.54)	16.72 (12.47)	3.99 (2.98)	20.76 (15.48)
BSCD2 G/KW HR (G/HP HR)	972.12 (724.91)	944.10 (704.01)	781.17 (582.52)	909.76 (678.41)
BSNOX G/KW HR (G/HP HR)	4.38 (3.27)	4.43 (3.30)	4.57 (3.41)	4.77 (3.56)
BSFC KG/KW HR (LB/HP HR)	.344 (.566)	.317 (.522)	.249 (.409)	.315 (.518)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.32 (23.23)
BSHC G/KW HR (G/HP HR)	8.83 (6.59) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	11.24 (8.39)
BSCD2 G/KW HR (G/HP HR)	852. (635.)
BSNOX G/KW HR (G/HP HR)	4.55 (3.39) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.282 (.463)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	46.769
	G/KWHR(G/HPHR)	2.70 (2.01)
	G/KG FUEL (G/LB FUEL)	9.58 (4.34)
	FILTER EFF.	96.2

TABLE C-11. HIGH ALTITUDE STEADY-STATE IDLE MODE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. HA-1-55 RUN1
DATE 6/13/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 736.85 MM HG(29.01 IN HG)
DRY BULB TEMP. (ENG.) 29.4 DEG C(85.0 DEG F)

RELATIVE HUMIDITY, ENGINE-55. PCT, CVS-45. PCT ENG. DEW PT. 67.2 DEG F
ABSOLUTE HUMIDITY (ENG.) 14.8 GM/KG(103.4 GRAINS/LB) NOX HUMIDITY C.F. 1.0798

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	300.0
TOT. BLOWER RATE SCMM (SCFM)	51.24 (1809.2)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.48)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	769.2 (27160.)
HC SAMPLE METER/RANGE/PPM	59.6/44/ 474.96
HC BCKGRD METER/RANGE/PPM	1.3/44/ 10.20
CO SAMPLE METER/RANGE/PPM	54.0/12/ 63.49
CO BCKGRD METER/RANGE/PPM	.0/12/ .00
CO2 SAMPLE METER/RANGE/PCT	50.3/12/ .0942
CO2 BCKGRD METER/RANGE/PCT	22.8/12/ .0358
NOX SAMPLE METER/RANGE/PPM	1.1/43/ 2.72
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .13
DILUTION FACTOR	90.58
HC CONCENTRATION PPM	464.87
CO CONCENTRATION PPM	52.45
CO2 CONCENTRATION PCT	.0588
NOX CONCENTRATION PPM	2.52
HC MASS GRAMS	206.185
CO MASS GRAMS	55.922
CO2 MASS GRAMS	827.92
NOX MASS GRAMS	4.008
FUEL KG (LB)	.494 (1.09)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS
BOTH FILTERS USED FOR PARTICULATE
90MM PARTICULATE RATES GRAMS/TEST

41.399

G/KG FUEL (G/LB FUEL) 83.85 (38.03)
FILTER EFF. 92.7

**TABLE C-12. HIGH ALTITUDE STEADY-STATE INTERMEDIATE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 1**

ENGINE NO.	TEST NO. HA-1-SS	RUN1
ENGINE MODEL 84 CUMMINS NTC 350	DATE 6/13/89	
ENGINE 14.0 L(855. CID) I-6	TIME	DIESEL EM-834-F
CVS NO. 27	DYNO NO. 4	BAG CART NO. 2

BAROMETER 736.35 MM HG(28.99 IN HG)	RELATIVE HUMIDITY, ENGINE-57. PCT, CVS-41. PCT	ENG. DEW PT. 66.2 DEG F
DRY BULB TEMP. (ENG.) 28.3 DEG C(83.0 DEG F)	ABSOLUTE HUMIDITY (ENG.) 14.3 GM/KG(99.9 GRAINS/LB)	NOX HUMIDITY C.F. 1.0692

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	300.2
TOT. BLOWER RATE SCMH (SCFM)	51.31 (1811.7)
TOT. 90MM RATE SCMH (SCFM)	.02 (.59)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	770.1 (27191.)

HC SAMPLE METER/RANGE/PPM	7.1/43/ 28.34
HC BCKGRD METER/RANGE/PPM	1.1/43/ 4.40
CO SAMPLE METER/RANGE/PPM	44.8/14/196.10
CO BCKGRD METER/RANGE/PPM	.0/14/ .00
CO2 SAMPLE METER/RANGE/PCT	75.0/ 1/1.3839
CO2 BCKGRD METER/RANGE/PCT	2.2/ 1/ .0388
NOX SAMPLE METER/RANGE/PPM	31.3/43/ 78.29
NOX BCKGRD METER/RANGE/PPM	.0/ 2/ .00

DILUTION FACTOR	9.53
HC CONCENTRATION PPM	24.41
CO CONCENTRATION PPM	188.29
CO2 CONCENTRATION PCT	1.3491
NOX CONCENTRATION PPM	75.54

HC MASS GRAMS	10.837
CO MASS GRAMS	168.793
CO2 MASS GRAMS	19005.75
NOX MASS GRAMS	118.941
FUEL KG (LB)	6.062 (13.36)
KW HR (HP HR)	24.54 (32.91)

BSHC G/KW HR (G/HP HR)	.44 (.33)
BSCO G/KW HR (G/HP HR)	6.88 (5.13)
BSCO2 G/KW HR (G/HP HR)	774.45 (577.51)
BSNOX G/KW HR (G/HP HR)	4.85 (3.61)
BSFC KG/KW HR (LB/HP HR)	.247 (.406)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	24.54 (32.91)
BSHC G/KW HR (G/HP HR)	.44 (.33) (CONTINUOUS)
BSCO G/KW HR (G/HP HR)	6.88 (5.13)
BSCO2 G/KW HR (G/HP HR)	774. (578.)
BSNOX G/KW HR (G/HP HR)	4.85 (3.61) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.247 (.406)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	37.658
	G/KWHR(G/HPHR)	1.53 (1.14)
	G/KG FUEL (G/LB FUEL)	6.21 (2.82)
	FILTER EFF.	97.2

**TABLE C-13. HIGH ALTITUDE COLD-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855, CID) I-6
CVS NO. 27

TEST NO. HA-2 RUN1
DATE 6/14/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 739.39 MM HG(29.11 IN HG)
DRY BULB TEMP. (ENG.) 26.1 DEG C(79.0 DEG F)

RELATIVE HUMIDITY , ENGINE-63, PCT , CVS-61, PCT ENG. DEW PT. 65.5 DEG F
ABSOLUTE HUMIDITY (ENG.) 13.9 GM/KG(97.0 GRAINS/LB) NOX HUMIDITY C.F. 1.0607

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAFF	NYNF
TIME SECONDS	296.9	300.4	300.4	305.9
TOT. BLOWER RATE SCMH (SCFM)	52.35 (1848.5)	52.82 (1865.0)	51.60 (1821.9)	51.20 (1807.8)
TOT. BMMH RATE SCMH (SCFM)	.02 (.71)	.02 (.71)	.02 (.71)	.02 (.71)
TOT. BOX20 RATE SCMH (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	259.2 (9151.)	254.5 (9041.)	258.4 (9125.)	261.1 (9220.)
HC SAMPLE METER/RANGE/PPM	32.1/44/ 739.86	55.4/44/ 520.92	17.5/44/ 139.32	43.1/44/ 344.23
HC BCKGRD METER/RANGE/PPM	1.7/44/ 13.34	1.7/44/ 13.34	1.7/44/ 13.34	1.7/44/ 13.34
CO SAMPLE METER/RANGE/PPM	98.4/13/216.99	77.7/13/187.91	67.6/13/161.28	72.5/13/174.10
CO BCKGRD METER/RANGE/PPM	7.2/13/ 16.43	5.0/13/ 11.42	4.2/13/ 3.59	2.6/13/ 5.94
CO2 SAMPLE METER/RANGE/PCT	76.5/14/ .5985	34.8/14/ .7514	37.2/ 1/1.8117	70.4/14/ .5051
CO2 BCKGRD METER/RANGE/PCT	21.6/14/ .0814	21.4/14/ .0804	5.8/ 1/ .1028	19.0/14/ .0692
NOX SAMPLE METER/RANGE/PPM	9.1/43/ 22.67	12.1/43/ 30.19	35.2/43/ 88.07	8.9/43/ 22.24
NOX BCKGRD METER/RANGE/PPM	5.7/ 1/ 1.49	1.6/ 2/ 1.61	3.3/ 2/ 3.32	1.6/ 2/ 1.61
DILUTION FACTOR	19.32	16.31	7.28	24.08
HC CONCENTRATION PPM	727.21	508.39	127.81	331.44
CO CONCENTRATION PPM	194.93	170.98	144.37	163.39
CO2 CONCENTRATION PCT	.5213	.6759	1.7230	.4388
NOX CONCENTRATION PPM	20.63	27.81	51.80	20.10
HC MASS GRAMS	108.667	77.549	19.046	49.903
CO MASS GRAMS	58.810	52.656	43.435	49.669
CO2 MASS GRAMS	2471.54	3270.95	8146.38	2096.06
NOX MASS GRAMS	10.847	14.924	42.882	10.648
FUEL KG (LB)	.914 (2.01)	1.131 (2.49)	2.599 (5.73)	.733 (1.62)
KW HR (HP HR)	1.92 (2.57)	3.20 (4.29)	9.66 (12.96)	2.12 (2.84)
BSHC G/KW HR (G/HP HR)	56.70 (42.28)	24.24 (18.08)	1.97 (1.47)	23.56 (17.57)
BSCD G/KW HR (G/HP HR)	30.69 (22.88)	16.46 (12.27)	4.49 (3.35)	23.45 (17.49)
BSCD2 G/KW HR (G/HP HR)	1289.65 (961.69)	1022.47 (762.46)	842.94 (628.58)	389.74 (738.05)
BSNOX G/KW HR (G/HP HR)	5.66 (4.22)	4.67 (3.48)	4.44 (3.31)	5.03 (3.75)
BSFC KG/KW HR (LB/HP HR)	.477 (.784)	.353 (.581)	.269 (.442)	.346 (.569)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.90 (22.66)
BSHC G/KW HR (G/HP HR)	15.10 (11.26) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	12.11 (9.03)
BSCD2 G/KW HR (G/HP HR)	346. (705.)
BSNOX G/KW HR (G/HP HR)	4.69 (3.50) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.318 (.523)

**PARTICULATE RESULTS, TOTAL FOR 4 BAGS
BOTH FILTERS USED FOR PARTICULATE**

90MM PARTICULATE RATES	GRAMS/TEST	64.001
G/KWHR (G/HPHR)	3.79 (2.82)	
G/KG FUEL (G/LB FUEL)	11.91 (5.40)	
FILTER EFF.	92.9	

C-14

**TABLE C-14. HIGH ALTITUDE HOT-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. HA-2 RUN1
DATE 6/14/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 739.39 MM HG(29.11 IN HG)
DRY BULB TEMP. (ENG.) 26.7 DEG C(80.0 DEG F)

RELATIVE HUMIDITY, ENGINE-57. PCT, CVS-55. PCT ENG. DEW PT. 63.5 DEG F
ABSOLUTE HUMIDITY (ENG.) 12.9 GM/KG(90.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0415

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LAF	LAF	NYNF
TIME SECONDS	296.8	306.0	299.7	305.6
TOT. BLOWER RATE SCMM (SCFM)	51.36 (1813.5)	50.39 (1779.3)	50.33 (1777.1)	49.82 (1759.0)
TOT. 90MM RATE SCMM (SCFM)	.02 (.69)	.02 (.69)	.02 (.69)	.02 (.69)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)	.00 (.0)	.00 (.0)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	254.2 (8974.7)	257.1 (9078.7)	251.5 (8880.7)	253.8 (8963.7)
HC SAMPLE METER/RANGE/PPM	72.2/44/ 575.24	38.0/44/ 303.64	13.3/44/ 105.31	39.4/44/ 315.31
HC BCKGRD METER/RANGE/PPM	1.6/44/ 12.55	1.6/44/ 12.55	1.6/44/ 12.55	1.6/44/ 12.55
CO SAMPLE METER/RANGE/PPM	87.4/13/214.23	81.1/13/197.05	52.0/13/146.87	59.0/13/164.92
CO BCKGRD METER/RANGE/PPM	1.7/13/ 3.88	2.3/13/ 5.25	2.1/13/ 4.80	2.0/13/ 4.57
CO2 SAMPLE METER/RANGE/PCT	70.4/14/ .5051	83.5/14/ .7251	93.0/ 1/1.7292	69.9/14/ .4981
CO2 BCKGRD METER/RANGE/PCT	13.8/14/ .0470	16.0/14/ .0561	4.8/ 1/ .0849	17.1/14/ .0608
NOX SAMPLE METER/RANGE/PPM	8.1/43/ 20.13	12.2/43/ 30.47	37.9/43/ 94.64	9.0/43/ 22.61
NOX BCKGRD METER/RANGE/PPM	1.7/ 1/ .45	.5/ 2/ .50	2.2/ 2/ 2.22	1.0/ 2/ 1.01
DILUTION FACTOR	22.97	17.30	7.64	24.56
HC CONCENTRATION PPM	563.23	291.81	94.40	303.27
CO CONCENTRATION PPM	204.71	185.95	135.29	156.12
CO2 CONCENTRATION PCT	.4602	.5723	1.6554	.4398
NOX CONCENTRATION PPM	19.20	29.17	89.23	21.08
HC MASS GRAMS	32.541	43.260	13.688	44.386
CO MASS GRAMS	50.570	55.657	39.610	46.133
CO2 MASS GRAMS	2139.67	3162.05	7615.98	2042.05
NOX MASS GRAMS	9.719	14.937	44.722	10.660
FUEL KG (LB)	.784 (1.73)	1.064 (2.34)	2.425 (5.35)	.708 (1.56)
KW HR (HP HR)	2.08 (2.79)	3.25 (4.36)	9.67 (12.97)	2.16 (2.89)
BSHC G/KW HR (G/HP HR)	39.67 (29.58)	13.31 (9.92)	1.42 (1.06)	20.60 (15.36)
BSCD G/KW HR (G/HP HR)	29.11 (21.71)	17.12 (12.77)	4.10 (3.05)	21.41 (15.96)
BSCD2 G/KW HR (G/HP HR)	1028.44 (766.91)	972.56 (725.24)	787.45 (587.20)	947.56 (706.59)
BSNOX G/KW HR (G/HP HR)	4.67 (3.48)	4.59 (3.43)	4.62 (3.45)	4.95 (3.69)
BSFC KG/KW HR (LB/HP HR)	.377 (.620)	.327 (.538)	.251 (.412)	.329 (.540)

TOTAL TEST RESULTS 4 BAGS

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

BOTH FILTERS USED FOR PARTICULATE

TOTAL KW HR (HP HR)	17.16 (23.01)	90MM PARTICULATE RATES	GRAMS/TEST	53.740
BSHC G/KW HR (G/HP HR)	10.72 (7.99) (CONTINUOUS)		G/KWHR(G/HPHR)	3.13 (2.34)
BSCD G/KW HR (G/HP HR)	11.77 (8.78)		G/KG FUEL (G/LB FUEL)	10.79 (4.89)
BSCD2 G/KW HR (G/HP HR)	372. (650.)		FILTER EFF.	92.0
BSNOX G/KW HR (G/HP HR)	4.66 (3.48) (CONTINUOUS)	C-15		
BSFC KG/KW HR (LB/HP HR)	.290 (.477)			

**TABLE C-15. HIGH ALTITUDE STEADY-STATE IDLE MODE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. HA-2 RUN1
DATE 6/14/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 739.14 MM HG(29.10 IN HG)
DRY BULB TEMP. (ENG.) 26.7 DEG C(80.0 DEG F)

RELATIVE HUMIDITY , ENGINE-61. PCT , CVS-58. PCT ENG. DEW PT. 65.5 DEG F
ABSOLUTE HUMIDITY (ENG.) 13.9 GM/KG(97.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0608

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	900.0
TOT. BLOWER RATE SCMM (SCFM)	50.90 (1797.1)
TOT. 30MM RATE SCMM (SCFM)	.02 (.73)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	763.7 (26968.1)

HC SAMPLE METER/RANGE/PPM	99.9/44/ 720.91
HC BCKGRD METER/RANGE/PPM	2.3/44/ 18.06
CO SAMPLE METER/RANGE/PPM	44.7/13/103.88
CO BCKGRD METER/RANGE/PPM	1.9/13/ 4.34
CO2 SAMPLE METER/RANGE/PCT	77.1/12/ .1706
CO2 BCKGRD METER/RANGE/PCT	36.7/12/ .0630
NOX SAMPLE METER/RANGE/PPM	1.8/43/ 4.40
NOX BCKGRD METER/RANGE/PPM	1.9/ 1/ .50

DILUTION FACTOR	53.00
HC CONCENTRATION PPM	703.19
CO CONCENTRATION PPM	97.41
CO2 CONCENTRATION PCT	.1088
NOX CONCENTRATION PPM	3.81

HC MASS GRAMS	309.672
CO MASS GRAMS	86.612
CO2 MASS GRAMS	1519.59
NOX MASS GRAMS	5.896
FUEL #3 (LB)	.830 (1.83)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS
BOTH FILTERS USED FOR PARTICULATE
90MM PARTICULATE RATES GRAMS/TEST

72.655

G/KG FUEL (G/LB FUEL) 87.58 (39.72)
FILTER EFF. 91.3

**TABLE C-16. HIGH ALTITUDE STEADY-STATE INTERMEDIATE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH FIXED RETARDED TIMING - RUN 2**

ENGINE NO.	TEST NO. HA-2	RUN1
ENGINE MODEL 34 CUMMINS NTC 350	DATE 6/14/89	
ENGINE 14.0 L(855. CID) I-6	TIME	DIESEL EM-834-F
CVS NO. 27	DVNO NO. -	BAG CART NO. 2

BAROMETER 738.89 MM HG(29.09 IN HG)	RELATIVE HUMIDITY, ENGINE-61. PCT, CVS-54. PCT	ENG. DEW PT. 67.0 DEG F
DRY BULB TEMP. (ENG.) 27.8 DEG C(82.0 DEG F)	ABSOLUTE HUMIDITY (ENG.) 14.6 GM/KG(102.4 GRAINS/LB)	NOX HUMIDITY C.F. 1.0767

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	300.2
TOT. BLOWER RATE SCMH (SCFM)	50.57 (1785.7)
TOT. 30MM RATE SCMH (SCFM)	.01 (.51)
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	753.0 (26799.)
HC SAMPLE METER/RANGE/PPM	6.2/43/ 32.99
HC BCKGRD METER/RANGE/PPM	2.5/43/ 10.00
CO SAMPLE METER/RANGE/PPM	82.0/13/199.49
CO BCKGRD METER/RANGE/PPM	2.1/13/ 4.80
CO2 SAMPLE METER/RANGE/PCT	75.5/ 1/1.3933
CO2 BCKGRD METER/RANGE/PCT	4.3/ 1/ .0760
NOX SAMPLE METER/RANGE/PPM	30.6/43/ 76.53
NOX BCKGRD METER/RANGE/PPM	1.8/ 2/ 1.81
DILUTION FACTOR	9.47
HC CONCENTRATION PPM	23.94
CO CONCENTRATION PPM	186.47
CO2 CONCENTRATION PCT	1.3253
NOX CONCENTRATION PPM	72.19
HC MASS GRAMS	10.479
CO MASS GRAMS	164.761
CO2 MASS GRAMS	19401.71
NOX MASS GRAMS	112.823
FUEL KG (LB)	5.870 (12.94)
KW HR (HP HR)	24.97 (33.49)
BSHC G/KW HR (G/HP HR)	.42 (.31)
BSCD G/KW HR (G/HP HR)	6.60 (4.92)
BSCD2 G/KW HR (G/HP HR)	736.85 (549.47)
BSNOX G/KW HR (G/HP HR)	4.52 (3.37)
BSFC KG/KW HR (LB/HP HR)	.235 (.386)

TOTAL TEST RESULTS 1 BAGS

PARTICULATE RESULTS. TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

TOTAL KW HR (HP HR)	24.97 (33.49)
BSHC G/KW HR (G/HP HR)	.42 (.31) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	6.60 (4.92)
BSCD2 G/KW HR (G/HP HR)	737. (549.)
BSNOX G/KW HR (G/HP HR)	4.52 (3.37) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.235 (.386)

30MM PARTICULATE RATES	GRAMS/TEST	39.071
	G/KWHR(G/HPHR)	1.56 (1.17)
	G/KG FUEL (G/LB FUEL)	6.66 (3.02)
	FILTER EFF.	97.5

**TABLE C-17. LOW ALTITUDE HOT-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH VARIABLE TIMING OPERATING NORMALLY**

ENGINE NO.
ENGINE MODEL 84 CUMMINS NTC 350
ENGINE 14.0 L(855. CID) I-6
CVS NO. 27

TEST NO. LA-3 RUN1
DATE 6/16/89
TIME
DYNO NO. 4

DIESEL EM-834-F
BAG CART NO. 2

BAROMETER 743.20 MM HG(29.26 IN HG)
DRY BULB TEMP. (ENG.) 30.6 DEG C(87.0 DEG F)

RELATIVE HUMIDITY, ENGINE-31. PCT, CVS-41. PCT ENG. DEW PT. 53.0 DEG F
ABSOLUTE HUMIDITY (ENG.) 8.7 GM/KG(61.2 GRAINS/LB) NOX HUMIDITY C.F. .9655

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.6
TOT. BLOWER RATE SCFM (SCFM)	52.31 (1847.1)
TOT. 90MM RATE SCFM (SCFM)	.03 (1.20)
TOT. 20X20 RATE SCFM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES(SCF)	1053.5 (37200.)
HC SAMPLE METER/RANGE/PPM	42.9/41/ 42.83
HC BCKGRD METER/RANGE/PPM	7.1/41/ 7.10
CO SAMPLE METER/RANGE/PPM	47.6/12/ 46.89
CO BCKGRD METER/RANGE/PPM	1.0/12/ 1.01
CO2 SAMPLE METER/RANGE/PCT	37.1/14/ .8004
CO2 BCKGRD METER/RANGE/PCT	14.7/14/ .0506
NOX SAMPLE METER/RANGE/PPM	25.8/43/ 64.44
NOX BCKGRD METER/RANGE/PPM	1.3/ 2/ 1.31

DILUTION FACTOR	16.56
HC CONCENTRATION PPM	36.17
CO CONCENTRATION PPM	44.61
CO2 CONCENTRATION PCT	.7528
NOX CONCENTRATION PPM	61.83

HC MASS GRAMS	21.970
CO MASS GRAMS	54.716
CO2 MASS GRAMS	14508.51
NOX MASS GRAMS	120.274
FUEL KG (LB)	4.605 (10.15)
KW HR (HP HR)	17.20 (23.07)

BSHC G/KW HR (G/HP HR)	1.28 (.95)
BSCD G/KW HR (G/HP HR)	3.18 (2.37)
BSCO2 G/KW HR (G/HP HR)	843.36 (628.89)
BSNOX G/KW HR (G/HP HR)	6.99 (5.21)
BSFC KG/KW HR (LB/HP HR)	.268 (.440)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	17.20 (23.07)
BSHC G/KW HR (G/HP HR)	1.28 (.95) (CONTINUOUS)
BSCD G/KW HR (G/HP HR)	3.18 (2.37)
BSCO2 G/KW HR (G/HP HR)	843. (629.)
BSNOX G/KW HR (G/HP HR)	6.99 (5.21) (CONTINUOUS)
BSFC KG/KW HR (LB/HP HR)	.268 (.440)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	10.819
	G/KWHR(G/HPHR)	.63 (.47)
	G/KG FUEL (G/LB FUEL)	2.35 (1.07)
	FILTER EFF.	96.4

TABLE C-18. LOW ALTITUDE STEADY-STATE IDLE MODE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH VARIABLE TIMING OPERATING NORMALLY

ENGINE NO.	TEST NO. WA-3	RUN1
ENGINE MODEL 84 CUMMINS NTC 350	DATE 6/16/89	
ENGINE 14.0 L(855. CID) I-6	TIME	DIESEL EM-834-F
CVS NO. 27	DYNO NO. 4	BAG CART NO. 2
BAROMETER 742.95 MM HG(29.25 IN HG)	RELATIVE HUMIDITY , ENGINE-38. PCT , CVS-39. PCT	ENG. DEW PT. 54.5 DEG F
DRY BULB TEMP. (ENG.) 28.3 DEG C(83.0 DEG F)	ABSOLUTE HUMIDITY (ENG.) 9.3 GM/KG(64.8 GRAINS/LB)	NOX HUMIDITY C.F. .9741
BAG RESULTS		
BAG NUMBER	1	
TIME SECONDS	900.0	
TOT. BLOWER RATE SCFM (SCFM)	52.55 (1855.4)	
TOT. 90MM RATE SCFM (SCFM)	.05 (1.63)	
TOT. 20X20 RATE SCFM (SCFM)	.00 (.0)	
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)	
TOTAL FLOW STD. CU. METRES(SCF)	788.9 (27856.)	
HC SAMPLE METER/RANGE/PPM	42.4/41/ 42.39	
HC BCKGRD METER/RANGE/PPM	7.7/41/ 7.70	
CO SAMPLE METER/RANGE/PPM	11.6/12/ 11.57	
CO BCKGRD METER/RANGE/PPM	.77/12/ .71	
CO2 SAMPLE METER/RANGE/PCT	61.9/12/ .1247	
CO2 BCKGRD METER/RANGE/PCT	24.3/12/ .0385	
NOX SAMPLE METER/RANGE/PPM	3.9/43/ 9.80	
NOX BCKGRD METER/RANGE/PPM	1.0/ 1/ .26	
DILUTION FACTOR	103.02	
HC CONCENTRATION PPM	34.77	
CO CONCENTRATION PPM	10.70	
CO2 CONCENTRATION PCT	.0866	
NOX CONCENTRATION PPM	9.38	
HC MASS GRAMS	15.817	
CO MASS GRAMS	9.828	
CO2 MASS GRAMS	1249.46	
NOX MASS GRAMS	13.792	
FUEL KG (LB)	.413 (.91)	

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES	GRAMS/TEST	2.168
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G/KG FUEL (G/LB FUEL)	5.25 (2.38)
FILTER EFF.	83.5

TABLE C-19. HIGH ALTITUDE HOT-START TRANSIENT EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH VARIABLE TIMING OPERATING NORMALLY

ENGINE NO.	TEST NO. HA-3	RUN1
ENGINE MODEL 84 CUMMINS NTC 350	DATE 6/15/89	
ENGINE 14.0 L (855. CID) I-6	TIME	
CVS NO. 27	DYNO NO. 4	DIESEL EM-834-F
		BAG CART NO. 2
BAROMETER 741.43 MM HG (29.19 IN HG)	RELATIVE HUMIDITY, ENGINE-36. PCT, CVS-31. PCT	ENG. DEW PT. 54.0 DEG F
DRY BULB TEMP. (ENG.) 28.9 DEG C (84.0 DEG F)	ABSOLUTE HUMIDITY (ENG.) 9.1 GM/KG (63.7 GRAINS/LB)	NOX HUMIDITY C.F. .9715

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.7
TOT. BLOWER RATE SCFM (SCFM)	51.61 (1822.4)
TOT. 30MM RATE SCFM (SCFM)	.03 (1.04)
TOT. 20X20 RATE SCFM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCFM (SCFM)	.00 (.00)
TOTAL FLOW STD. CU. METRES (SCF)	1040.3 (36734.)

HC SAMPLE METER/RANGE/PPM	53.5/41/ 53.50
HC BCKGRD METER/RANGE/PPM	10.7/41/ 10.69
CO SAMPLE METER/RANGE/PPM	87.2/12/ 87.37
CO BCKGRD METER/RANGE/PPM	.8/12/ .81
CO2 SAMPLE METER/RANGE/PCT	87.9/14/ .8182
CO2 BCKGRD METER/RANGE/PCT	16.7/14/ .0590
NOX SAMPLE METER/RANGE/PPM	23.6/43/ 58.99
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ .71

DILUTION FACTOR	16.11
HC CONCENTRATION PPM	43.47
CO CONCENTRATION PPM	84.35
CO2 CONCENTRATION PCT	.7628
NOX CONCENTRATION PPM	57.08

HC MASS GRAMS	26.075
CO MASS GRAMS	102.163
CO2 MASS GRAMS	14517.39
NOX MASS GRAMS	110.329
FUEL KG (LB)	4.635 (10.22)
KW HR (HP HR)	17.02 (22.83)

B5HC G/KW HR (G/HP HR)	1.53 (1.14)
B5CO G/KW HR (G/HP HR)	6.00 (4.47)
B5CO2 G/KW HR (G/HP HR)	852.74 (635.89)
B5NOX G/KW HR (G/HP HR)	6.48 (4.83)
B5FC KG/KW HR (LB/HP HR)	.272 (.448)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	17.02 (22.83)
B5HC G/KW HR (G/HP HR)	1.53 (1.14) (CONTINUOUS)
B5CO G/KW HR (G/HP HR)	6.00 (4.47)
B5CO2 G/KW HR (G/HP HR)	853. (636.)
B5NOX G/KW HR (G/HP HR)	6.48 (4.83) (CONTINUOUS)
B5FC KG/KW HR (LB/HP HR)	.272 (.448)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS
BOTH FILTERS USED FOR PARTICULATE
90MM PARTICULATE RATES

GRAMS/TEST	15.614
G/KW HR (G/HP HR)	.92 (.68)
G/KG FUEL (G/LB FUEL)	3.37 (1.53)
FILTER EFF.	96.8

TABLE C-20. HIGH ALTITUDE STEADY-STATE IDLE MODE EMISSION RESULTS
FOR THE CUMMINS NTC-350 WITH VARIABLE TIMING OPERATING NORMALLY

ENGINE NO.	TEST NO. HA-3	RUN1
ENGINE MODEL 84 CUMMINS NTC 350	DATE 6/15/89	
ENGINE 14.0 L(855. CID) I-6	TIME	DIESEL EM-834-F
CVS NO. 27	DYNO NO. 4	BAG CART NO. 2
BAROMETER 741.43 MM HG(29.19 IN HG)		
RELATIVE HUMIDITY, ENGINE-46. PCT, CVS-37. PCT ENG. DEW PT. 59.0 DEG F		
DRY BULB TEMP. (ENG.) 27.8 DEG C(82.0 DEG F)		
ABSOLUTE HUMIDITY (ENG.) 10.9 GM/KG(76.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0041		
BAG RESULTS		
BAG NUMBER	1	
TIME SECONDS	899.9	
TOT. BLOWER RATE SCMH (SCFM)	51.44 (1816.5)	
TOT. 90MM RATE SCMH (SCFM)	.03 (1.20)	
TOT. 20X20 RATE SCMH (SCFM)	.00 (.0)	
TOT. AUX. SAMPLE RATE SCMH (SCFM)	.00 (.00)	
TOTAL FLOW STD. CU. METRES(SCF)	772.1 (27262.)	
HC SAMPLE METER/RANGE/PPM	46.0/41/ 45.96	
HC BCKGRD METER/RANGE/PPM	10.1/41/ 10.09	
CO SAMPLE METER/RANGE/PPM	12.6/12/ 12.55	
CO BCKGRD METER/RANGE/PPM	.1/12/ .10	
CO2 SAMPLE METER/RANGE/PCT	72.4/12/ .1556	
CO2 BCKGRD METER/RANGE/PCT	31.9/12/ .0531	
NOX SAMPLE METER/RANGE/PPM	4.7/43/ 11.72	
NOX BCKGRD METER/RANGE/PPM	1.4/ 1/ .37	
DILUTION FACTOR	82.99	
HC CONCENTRATION PPM	35.99	
CO CONCENTRATION PPM	12.27	
CO2 CONCENTRATION PCT	.1032	
NOX CONCENTRATION PPM	11.15	
HC MASS GRAMS	16.023	
CO MASS GRAMS	11.025	
CO2 MASS GRAMS	1457.39	
NOX MASS GRAMS	16.532	
FUEL KG (LB)	.479 (1.06)	

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

BOTH FILTERS USED FOR PARTICULATE

90MM PARTICULATE RATES GRAMS/TEST 1.874

G/KG FUEL (G/LB FUEL) 3.91 (1.77)

FILTER EFF. 77.4

APPENDIX D

**TRANSIENT AND STEADY-STATE ALDEHYDE
RESULTS FROM CUMMINS NTC-350**

TABLE D-1. LOW ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE
CUMMINS NTC-350 - RUN 1 WITH FIXED RETARDED TIMING

Aldehyde	Cold-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	3,350	143
Acetaldehyde	1,470	63
Acrolein	874	37
Acetone	397	17
Propionaldehyde	580	25
Crotonaldehyde	254	11
Isobutyraldehyde + MEK	1,130	48
Benzaldehyde	504	22
Hexanaldehyde	423	18
Total Aldehydes	8,980	384

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	2,780	119
Acetaldehyde	1,170	50
Acrolein	889	38
Acetone	260	11
Propionaldehyde	457	20
Crotonaldehyde	218	9
Isobutyraldehyde + MEK	958	41
Benzaldehyde	454	19
Hexanaldehyde	536	23
Total Aldehydes	7,720	330

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	2,700	11,100
Acetaldehyde	1,210	4,850
Acrolein	734	2,940
Acetone	303	1,210
Propionaldehyde	455	1,820
Crotonaldehyde	199	795
Isobutyraldehyde + MEK	792	3,170
Benzaldehyde	436	1,740
Hexanaldehyde	314	1,260
Total Aldehydes	7,140	28,900

Aldehyde	1300 RPM at 50% Load	
	mg/test	mg/hp-hr
Formaldehyde	324	10
Acetaldehyde	99	3
Acrolein	69	2
Acetone	0	0
Propionaldehyde	32	1
Crotonaldehyde	14	0
Isobutyraldehyde + MEK	54	2
Benzaldehyde	21	1
Hexanaldehyde	18	1
Total Aldehydes	631	20

^aValues are generally considered usable to only two significant figures.

**TABLE D-2. LOW ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE
CUMMINS NTC-350 - RUN 2 WITH FIXED RETARDED TIMING**

Aldehyde	Cold-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	3,710	157
Acetaldehyde	1,550	65
Acrolein	838	35
Acetone	617	26
Propionaldehyde	640	27
Crotonaldehyde	310	13
Isobutyraldehyde + MEK	1,120	47
Benzaldehyde	532	22
Hexanaldehyde	629	35
Total Aldehydes	10,100	427

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	2,510	108
Acetaldehyde	1,190	51
Acrolein	623	27
Acetone	514	22
Propionaldehyde	440	19
Crotonaldehyde	228	10
Isobutyraldehyde + MEK	744	32
Benzaldehyde	359	15
Hexanaldehyde	638	27
Total Aldehydes	7,250	311

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	4,310	17,200
Acetaldehyde	1,920	7,690
Acrolein	1,170	4,700
Acetone	511	2,040
Propionaldehyde	737	2,950
Crotonaldehyde	259	1,040
Isobutyraldehyde + MEK	1,240	4,960
Benzaldehyde	432	1,730
Hexanaldehyde	485	1,940
Total Aldehydes	11,100	44,300

Aldehyde	1300 RPM at 50% Load	
	mg/test	mg/hp-hr
Formaldehyde	439	13
Acetaldehyde	154	5
Acrolein	181	6
Acetone	14	0
Propionaldehyde	56	2
Crotonaldehyde	30	1
Isobutyraldehyde + MEK	95	3
Benzaldehyde	47	2
Hexanaldehyde	37	1
Total Aldehydes	1,050	33

^aValues are generally considered usable to only two significant figures.

TABLE D-3. HIGH ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE CUMMINS NTC-350 - RUN 1 WITH FIXED RETARDED TIMING

Aldehyde	Cold-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	6,540	286
Acetaldehyde	2,860	125
Acrolein	1,590	70
Acetone	531	23
Propionaldehyde	1,080	47
Crotonaldehyde	337	15
Isobutyraldehyde + MEK	1,530	67
Benzaldehyde	557	24
Hexanaldehyde	717	31
Total Aldehydes	15,700	688

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	7,580	327
Acetaldehyde	3,470	149
Acrolein	2,070	89
Acetone	641	28
Propionaldehyde	1,480	64
Crotonaldehyde	666	29
Isobutyraldehyde + MEK	2,410	104
Benzaldehyde	1,200	52
Hexanaldehyde	1,630	70
Total Aldehydes	21,100	912

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	8,830	35,300
Acetaldehyde	4,290	17,200
Acrolein	2,390	9,570
Acetone	526	2,130
Propionaldehyde	1,860	7,420
Crotonaldehyde	803	3,210
Isobutyraldehyde + MEK	2,760	11,100
Benzaldehyde	1,410	5,630
Hexanaldehyde	1,760	7,040
Total Aldehydes	24,600	98,600

Aldehyde	1300 RPM at 50% Load	
	mg/test	mg/hp-hr
Formaldehyde	711	22
Acetaldehyde	234	7
Acrolein	250	8
Acetone	0	0
Propionaldehyde	74	2
Crotonaldehyde	44	2
Isobutyraldehyde + MEK	152	5
Benzaldehyde	105	3
Hexanaldehyde	40	1
Total Aldehydes	1,610	50

^aValues are generally considered usable to only two significant figures.

TABLE D-4. HIGH ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE
CUMMINS NTC-350 - RUN 2 WITH FIXED RETARDED TIMING

Aldehyde	Cold-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	6,590	291
Acetaldehyde	2,900	128
Acrolein	1,520	67
Acetone	589	26
Propionaldehyde	1,020	45
Crotonaldehyde	340	15
Isobutyraldehyde + MEK	1,380	61
Benzaldehyde	476	21
Hexanaldehyde	906	40
Total Aldehydes	15,700	694

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde		
Acetaldehyde		
Acrolein		
Acetone		
Propionaldehyde		
Crotonaldehyde		
Isobutyraldehyde + MEK		
Benzaldehyde		
Hexanaldehyde		
Total Aldehydes		

Aldehyde Sample Failure

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	13,500	54,100
Acetaldehyde	3,740	15,000
Acrolein	4,120	16,500
Acetone	0	0
Propionaldehyde	1,360	5,440
Crotonaldehyde	878	3510
Isobutyraldehyde + MEK	2,540	10,100
Benzaldehyde	1,610	6,440
Hexanaldehyde	1,560	6,230
Total Aldehydes	29,300	117,000

Aldehyde	1300 RPM at 50% Load	
	mg/test	mg/hp-hr
Formaldehyde	717	21
Acetaldehyde	263	8
Acrolein	321	10
Acetone	0	0
Propionaldehyde	75	2
Crotonaldehyde	45	1
Isobutyraldehyde + MEK	146	4
Benzaldehyde	99	3
Hexanaldehyde	75	2
Total Aldehydes	1,740	51

^aValues are generally considered usable to only two significant figures.

TABLE D-5. HIGH ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE CUMMINS NTC-350 - RUN 3 WITH VARIABLE TIMING OPERATING NORMALLY

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	1,740	76
Acetaldehyde	714	31
Acrolein	707	31
Acetone	130	6
Propionaldehyde	205	9
Crotonaldehyde	93	4
Isobutyraldehyde + MEK	494	22
Benzaldehyde	130	6
Hexanaldehyde	129	6
Total Aldehydes	4,340	191

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	717	2,870
Acetaldehyde	302	1,210
Acrolein	28	110
Acetone	90	360
Propionaldehyde	101	403
Crotonaldehyde	47	189
Isobutyraldehyde + MEK	213	851
Benzaldehyde	91	362
Hexanaldehyde	74	296
Total Aldehydes	1,660	6,650

^aValues are generally considered usable to only two significant figures.

TABLE D-6. LOW ALTITUDE ALDEHYDE EMISSION RESULTS^a FOR THE CUMMINS NTC-350 - RUN 3 WITH VARIABLE TIMING OPERATING NORMALLY

Aldehyde	Hot-Start Emissions	
	mg/test	mg/hp-hr
Formaldehyde	1,180	51
Acetaldehyde	454	20
Acrolein	331	14
Acetone	157	7
Propionaldehyde	114	5
Crotonaldehyde	62	3
Isobutyraldehyde + MEK	304	13
Benzaldehyde	96	4
Hexanaldehyde	94	4
Total Aldehydes	2,790	121

Aldehyde	Idle Emissions	
	mg/test	mg/hr
Formaldehyde	671	2,680
Acetaldehyde	285	1,140
Acrolein	321	1,290
Acetone	86	344
Propionaldehyde	78	310
Crotonaldehyde	34	138
Isobutyraldehyde + MEK	200	799
Benzaldehyde	122	490
Hexanaldehyde	45	181
Total Aldehydes	1,840	7,370

^aValues are generally considered usable to only two significant figures.